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HIP AND VALLEY DESIGN

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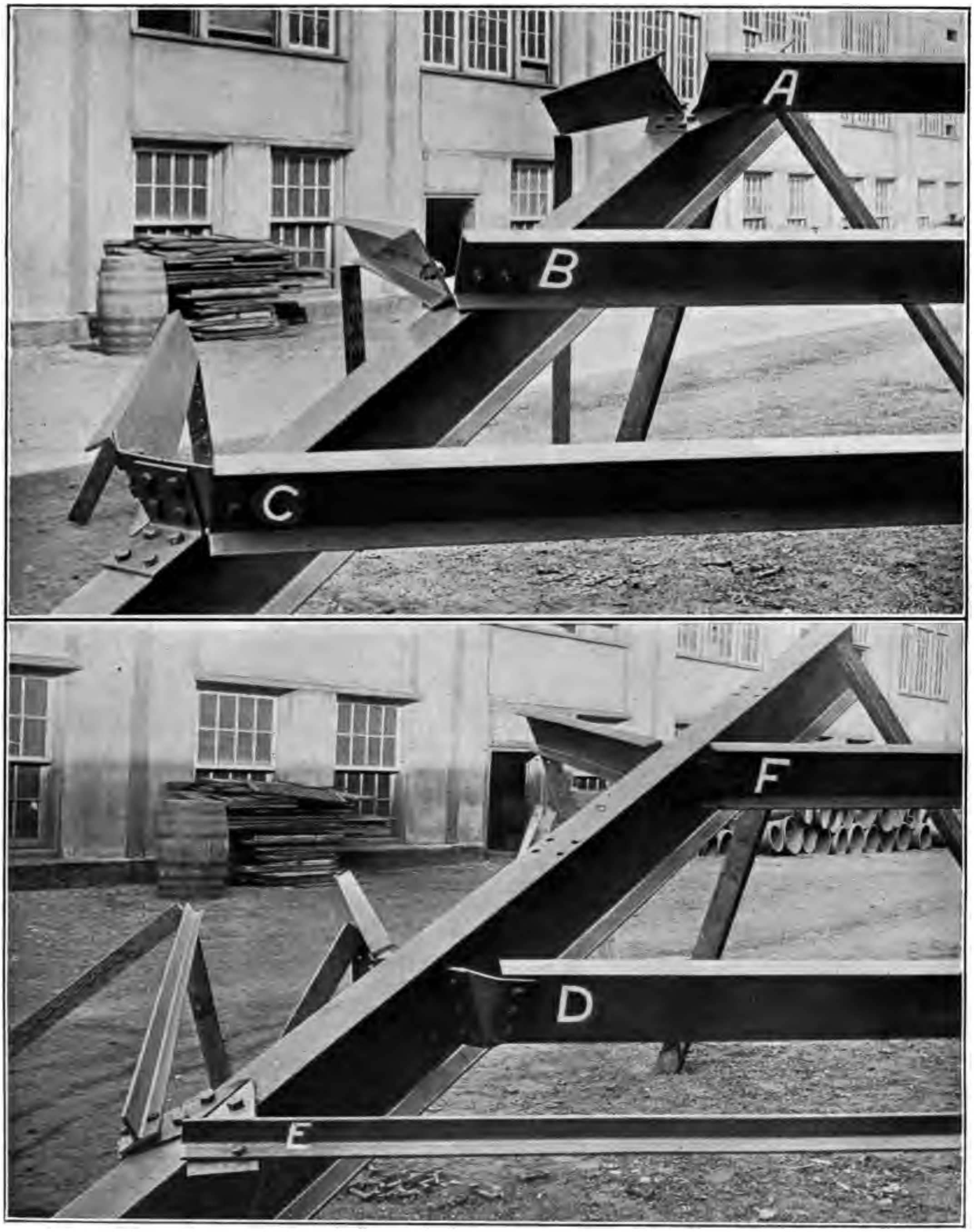
SIX STYLES OF HIP RAFTER CONNECTIONS



HIP AND VALLEY DESIGN

DETAILS, FORMULAE AND GRAPHICS

ROOFS

HOPPERS AND PIPE LINES

BY

H. L. McKIBBEN and L. E. GRAY

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Ambridge, Pennsylvania

First Edition, August 1, 1912

PREFACE.

The difficulty of making working shop drawings for roof connections at Hip and Valley is appreciated by Structural Engineers.

This book has been prepared to cover practical working details for such construction and to present the analytic and graphic processes needful for their development.

From the presentation of the designs here given, Engineers and Architects can determine the style of connection adapted to their demands readily and can specify the same for the structures they have in charge.

To Draftsmen the treatment of the subject will especially appeal, resulting to them in a saving of extra labor and concern.

Students will discover the practical training in descriptive geometry and trigonometry as applied to active engineering to be exceptionally valuable. Class room work in the proof of the formulae is recommended to Engineering Schools.

H. L. McKibben.

L. E. Gray.

Engineers with American Bridge Co.

FOREWORD.

On pages 3, 4 and 5 are shown working details for styles A, B, C, D, E and F, or six methods of connection to Hip Rafters from which to select the one that conforms best to the adjoining framing.

On pages 6, 7 and 8 are found working details for styles A, B, C, D, E and F, or six methods of similar connections to Valley Rafters from which to choose the one most desirable.

A sketch appears with each style of detail showing the position of the purlin in the main roof section, and small sub-formulae showing solutions for the variables y_1 to y_{10}, with special attention to y_1 and y_2.

After making selection of style desired, the detailer should solve the angles required as shown in details; i. e., $\angle 8$ and $\angle 9$ are needed in style C. No other angles need be found; only those involved in the style chosen.

Solution of these angles can be readily made from general formulae on page 10, if the worker be familiar with Trigonometry and Logarithms; if not, results may be obtained from the simple graphics given on pages 11, 12 and 13, making the problem easy for the detailer who is not familiar with formulae.

If the case in hand be one that is covered by the tabulated solutions on pages 14, 15 and 16, the worker can take from those tables any or all variables which develop in a roof of pitch $^1/_5$, $^1/_4$, $^1/_3$, 30° or 55°, if the angle B in plan is 30°, 45° or 50°.

These tabulated solutions give the values of the variables for designs in most common use without the necessity of solving any angles whatever; but the formulae on page 10 and graphics on pages 11, 12 and 13 furnish data for solving angles for any roof pitch and all possible positions of rafter.

In styles A, B, C and E the roof line being above the main truss metal line, the worker will need to use formulae on page 9 to locate working point "d."

The authors desire to call especial attention to the following:

1st. The known data are in all cases the main roof pitch or Angle A. The position of Hip or Valley Rafter, Angle B, which is the angle formed by rafter and main truss as seen in *Plan* looking directly perpendicular to lower side of Angle A. No other data than A and B as above described is ever required.

Throughout both details and graphics the letter "d" refers always to the same working point; the marks d_1 and d_2 refer also to this same point, viewed from different positions.

2d. All formulae on page 10 are logarithmic, and in terms of tangent functions.

3d. Use of the graphics on pages 11, 12 and 13 expedite the work and give accurate results.

4th. A short method of graphics for solution of Angles ***L5***, ***L6*** and ***L8*** also appears on page 10, which may be used after solving ***L3*** and ***L4***, if desired.

5th. For those desiring to follow out the proofs given on pages 21 to 29, the four major intersecting planes involved are as follows (see page 10):

ROOF PLANE.

Seen in Elevation of Truss as line ab.
Seen in Plan as inclined surface a_1, b_1, r_1.

PURLIN WEB PLANE.

Seen in Elevation of Truss as line c, d.
Seen in Plan as inclined surface d_1, c_1, e_1.

RAFTER WEB PLANE.

Seen in Elevation of Rafter as surface r_2, c_2, b_2.
Seen in Plan as line r_1, b_1.

RAFTER FLANGE PLANE.

Seen in Elevation of Rafter as line r_2, b_2.
Seen in Plan as inclined surface r_1, b_1, e_1.

6th. Other formulae which may be used if desired are as follows:

Cos ***L3***=Cos R Cos ***L1*** Sec A.
Tan ***L5***=Cos A Tan B Cos ***L1***.
Tan ***L5***=Tan ***L2*** Cos ***L1***.
Tan ***L7***=Sin A Sin B Cos ***L4***.
Tan ***L7***=Cos ***L2*** Tan ***L10***.

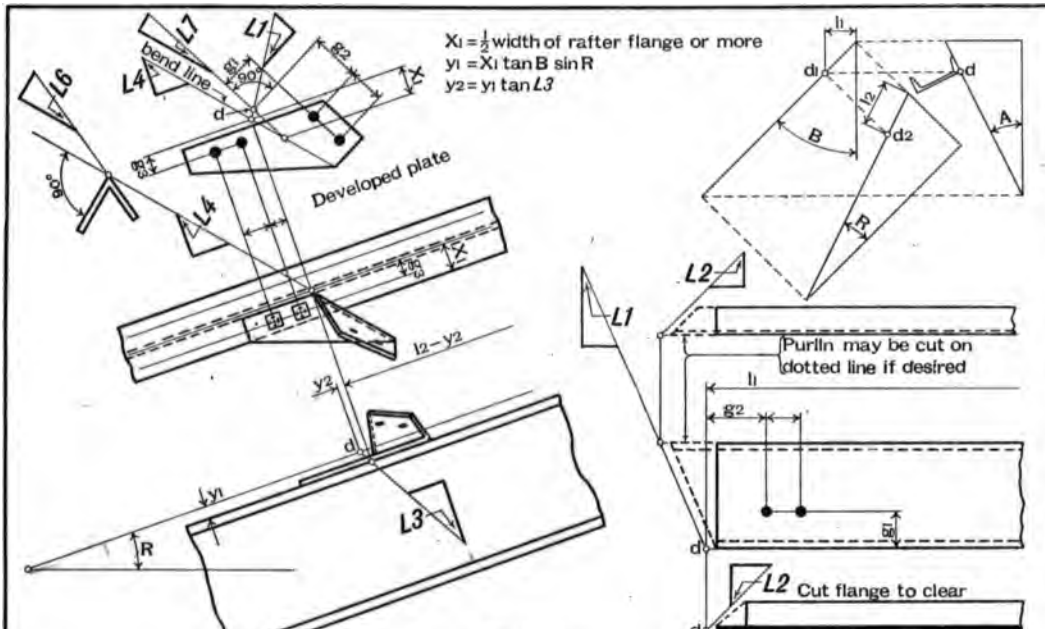
HOPPERS, BINS AND CHUTES (FORMS OF VALLEY CONSTRUCTION).

Details for these structures are left to the judgment of the detailer and are usually governed by the main design. The solution of the bend on connecting plate at dihedral intersections is the only difficulty for most draftsmen. Both formulae and graphics are provided on page 17 for ready use.

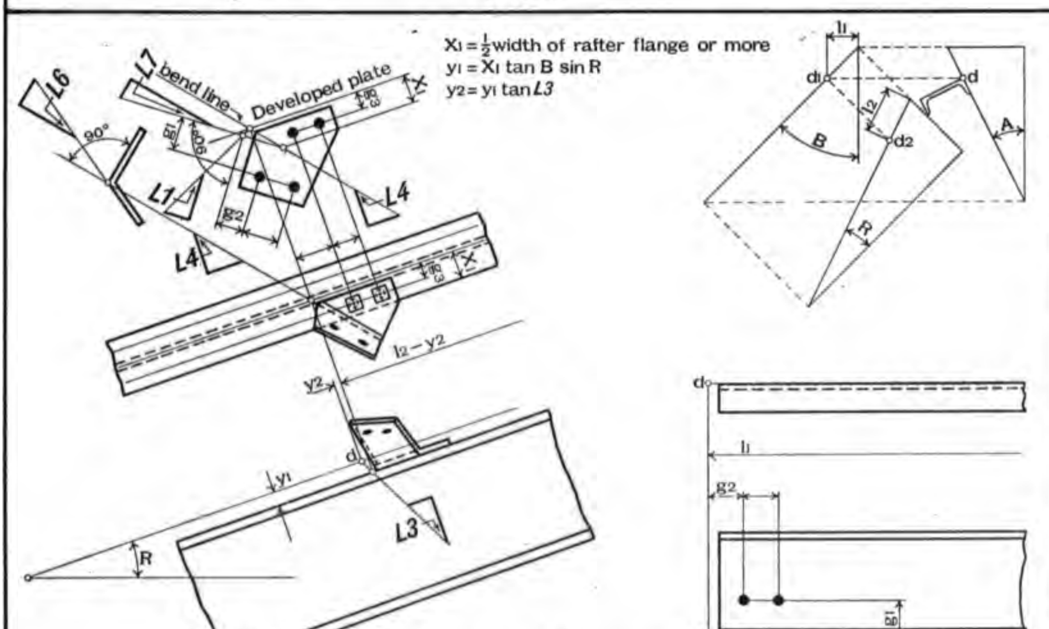
PIPE LINES.

Large Pipe Lines often require both horizontal and vertical change of direction at the same point, which condition may give rise to annoying details. Two separate bends are more expensive and produce greater friction on the flow than a single resultant bend. Careful attention to resultant angles ***"X"*** and detail angles ***"Y"*** will save much trouble in fabrication and improve the efficiency of the finished structure.

HIP RAFTER DETAILS



STYLE A.



STYLE B.

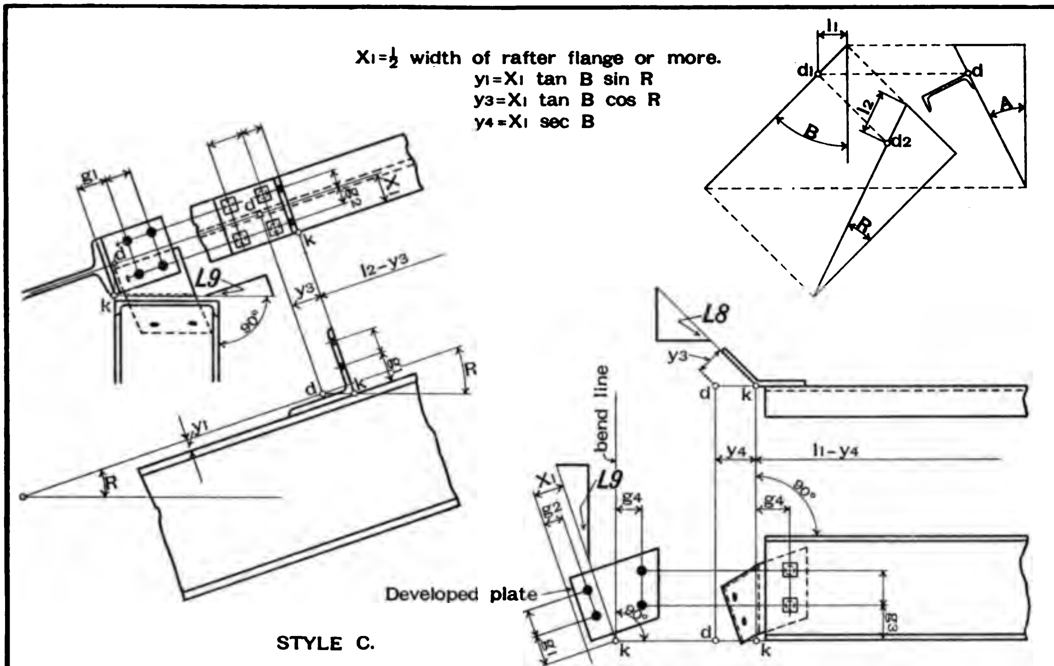
HIP RAFTER DETAILS

$X_1 = \frac{1}{2}$ width of rafter flange or more.

$y_1 = X_1 \tan B \sin R$

$y_3 = X_1 \tan B \cos R$

$y_4 = X_1 \sec B$



STYLE C.

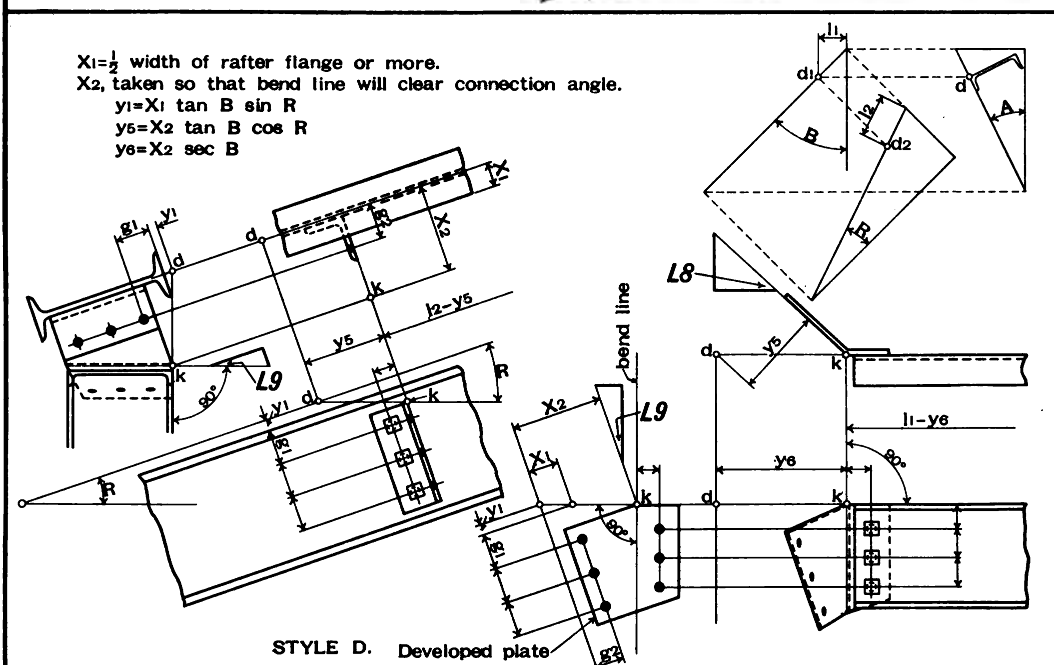
$X_1 = \frac{1}{2}$ width of rafter flange or more.

X_2, taken so that bend line will clear connection angle.

$y_1 = X_1 \tan B \sin R$

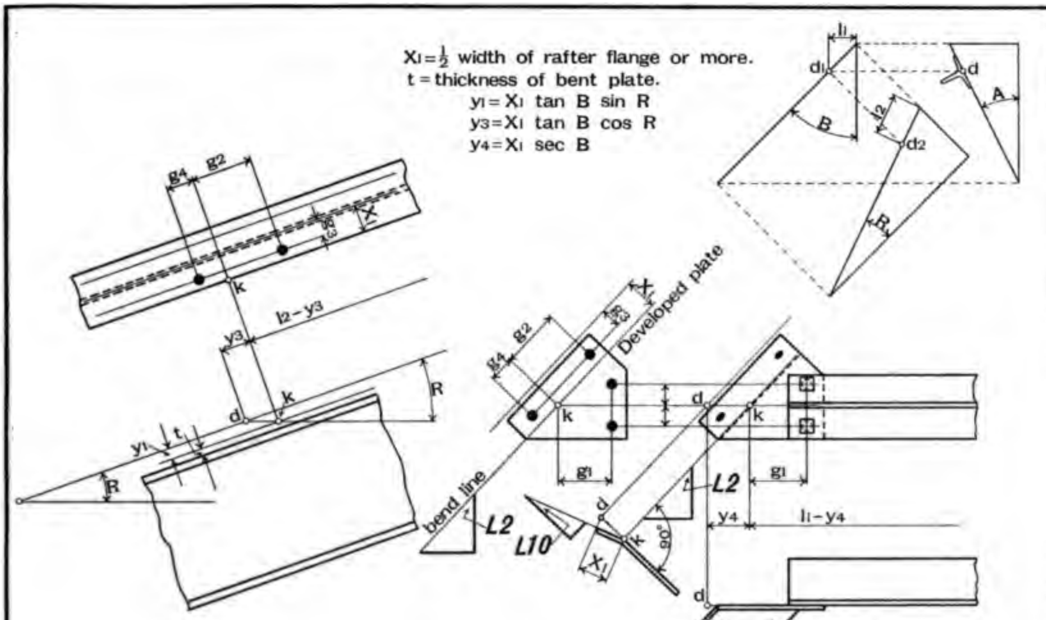
$y_5 = X_2 \tan B \cos R$

$y_6 = X_2 \sec B$

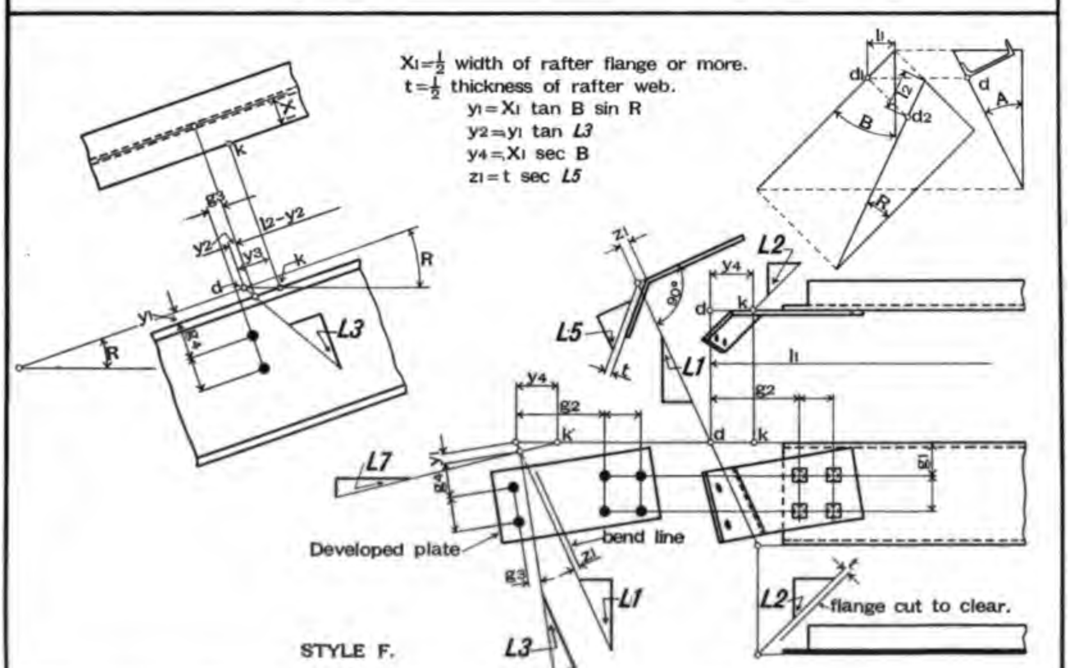


STYLE D. Developed plate

HIP RAFTER DETAILS

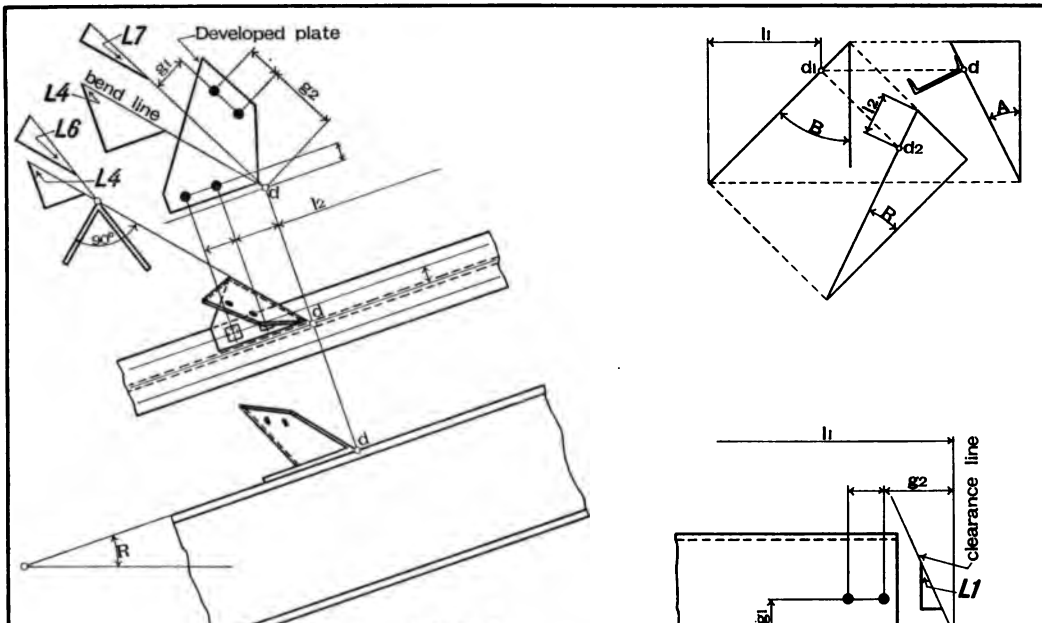


STYLE E.

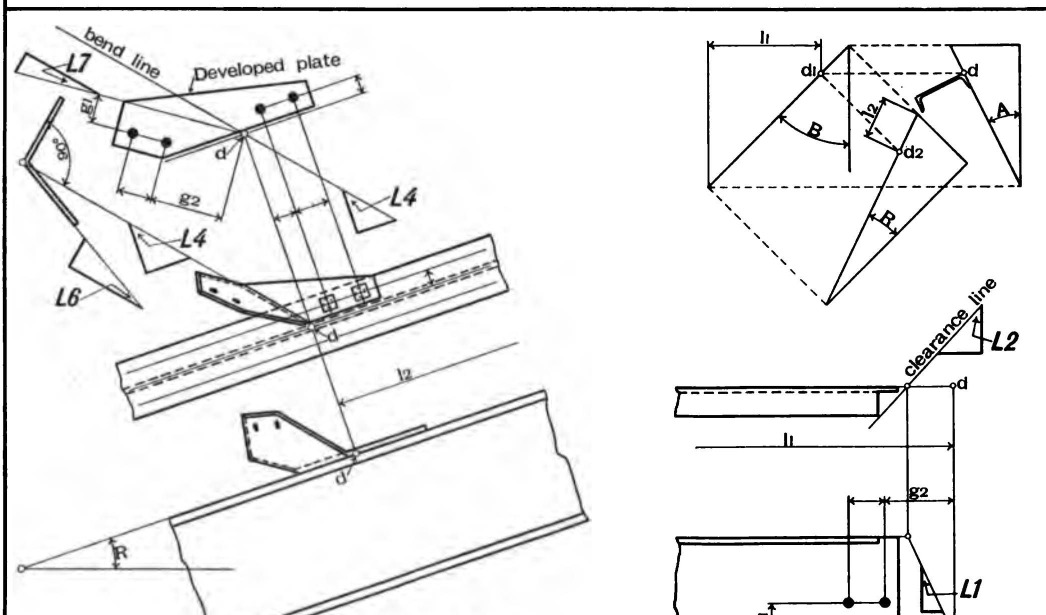


STYLE F.

VALLEY RAFTER DETAILS

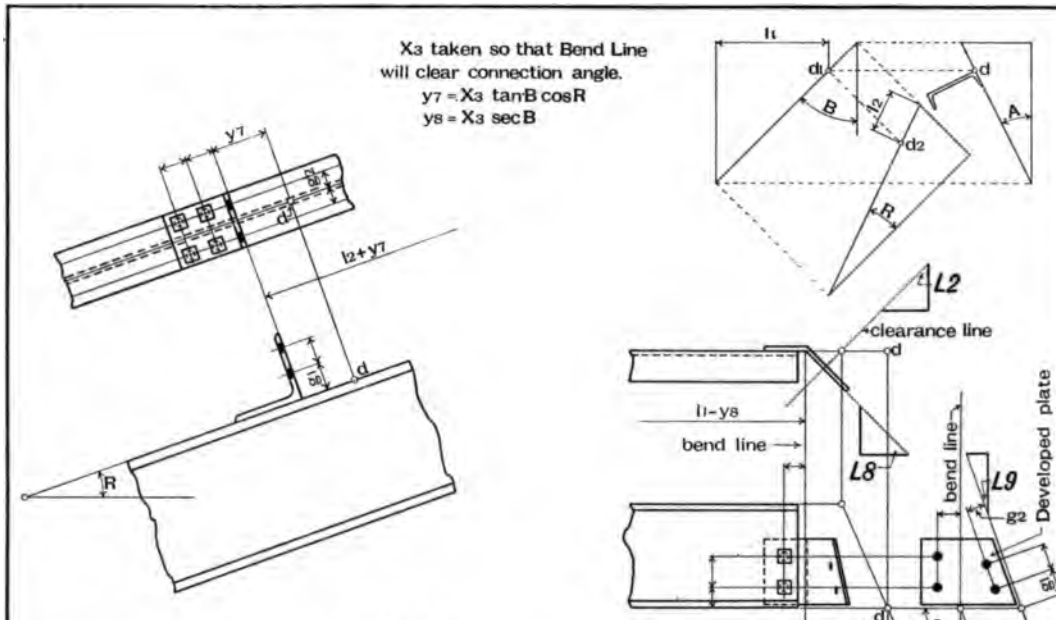


STYLE A.

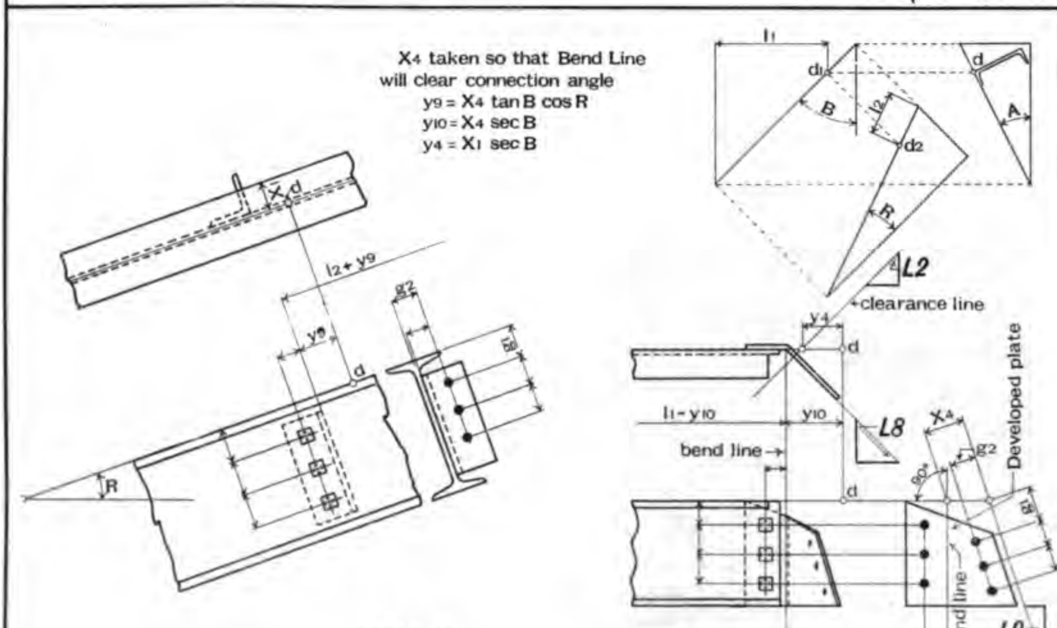


STYLE B.

VALLEY RAFTER DETAILS



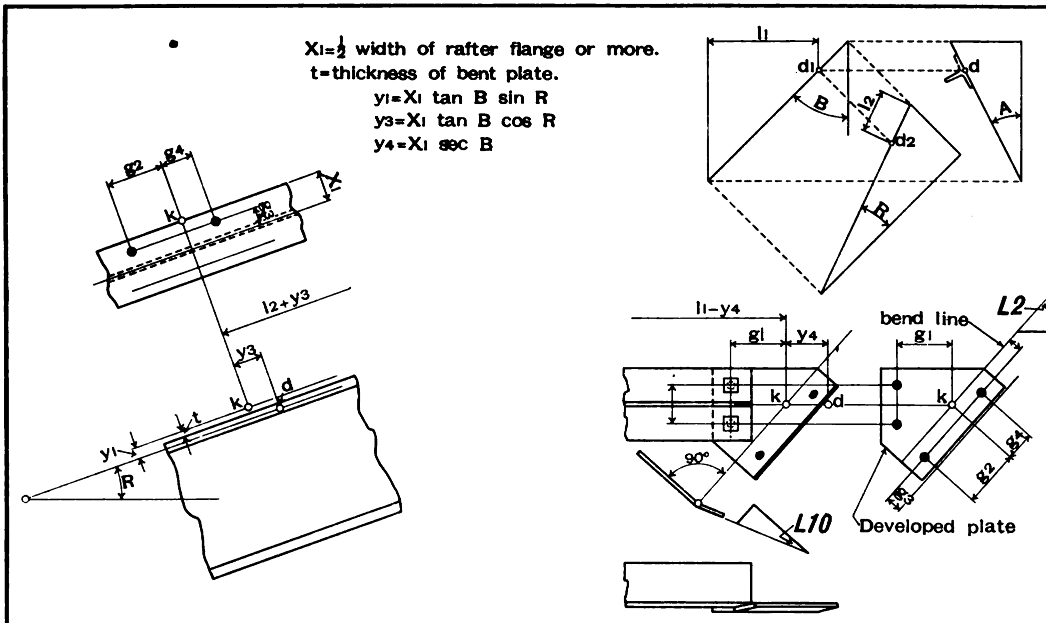
STYLE C.



STYLE D.

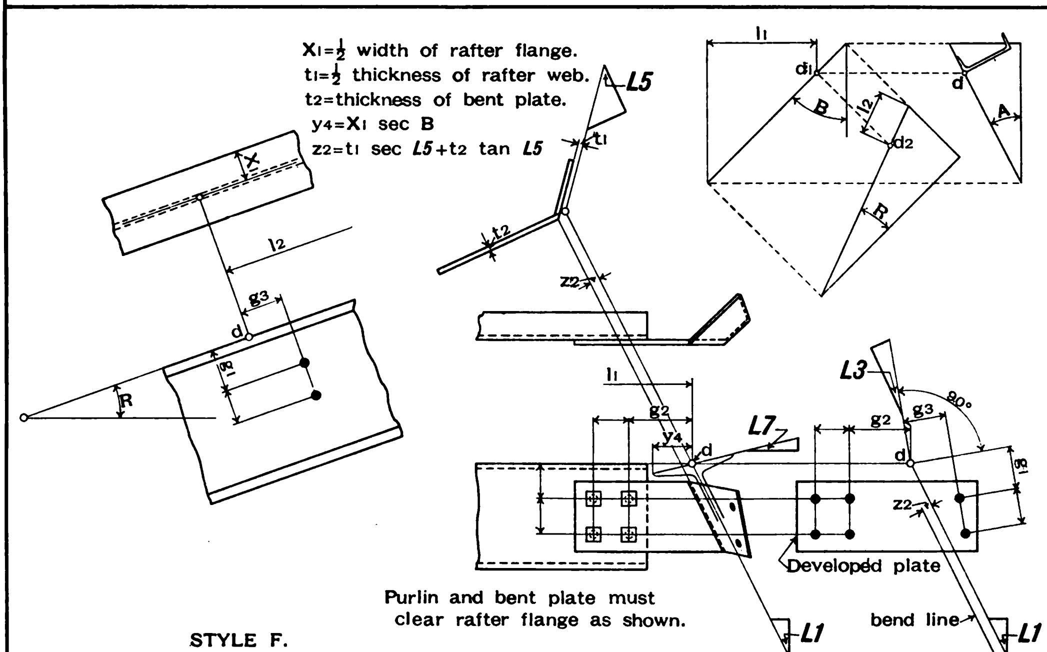
VALLEY RAFTER DETAILS

$X_1 = \frac{1}{2}$ width of rafter flange or more.
t = thickness of bent plate.
$y_1 = X_1 \tan B \sin R$
$y_3 = X_1 \tan B \cos R$
$y_4 = X_1 \sec B$



STYLE E.

$X_1 = \frac{1}{2}$ width of rafter flange.
$t_1 = \frac{1}{2}$ thickness of rafter web.
t_2 = thickness of bent plate.
$y_4 = X_1 \sec B$
$z_2 = t_1 \sec L5 + t_2 \tan L5$

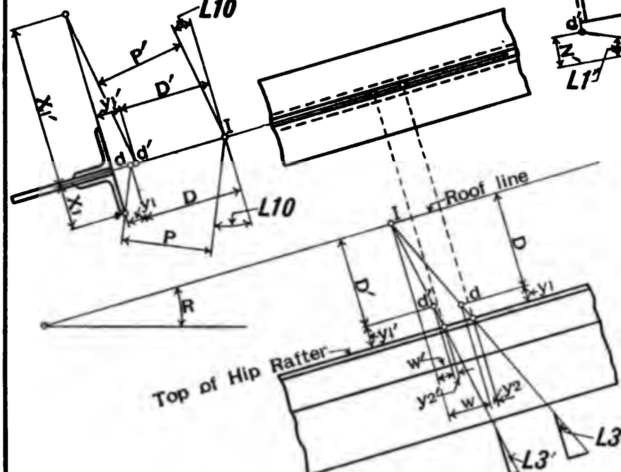


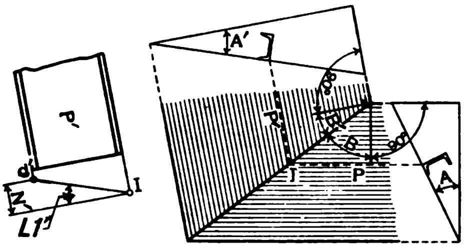
Purlin and bent plate must clear rafter flange as shown.

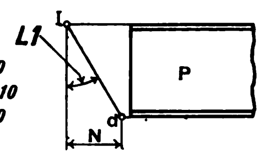
STYLE F.

RELATIONS OF ROOF LINE TO WORKING POINTS USED IN FORMULAE

Given:
- X_1 or $X_1' = \frac{1}{2}$ width of rafter flange or more.
- P = actual depth of purlin.
- P′ = " " " "







$D = P \sec \angle 10$

$y_1 = X_1 \tan \angle 10$

$D' = P' \sec \angle 10$

$y_1' = D + y_1 - D'$

$X_1' = y_1' \cot \angle 10'$

$y_2 = y_1 \tan \angle 3$

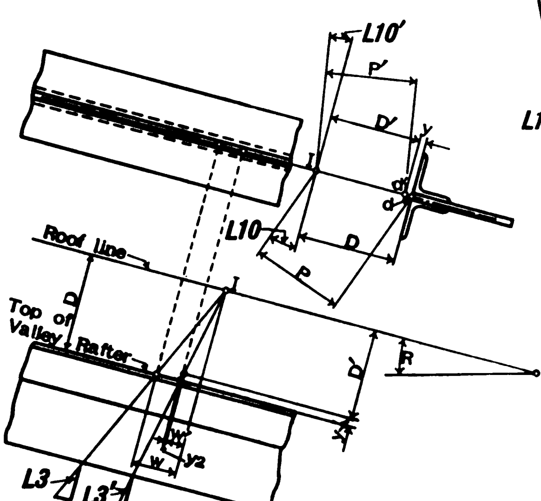
$y_2' = y_1' \tan \angle 3'$

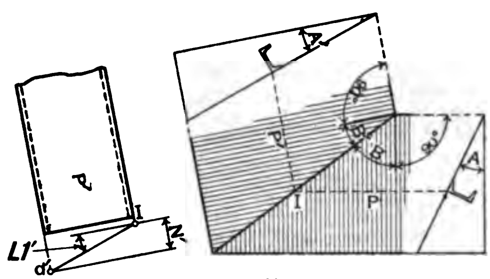
$w = D \tan \angle 3$

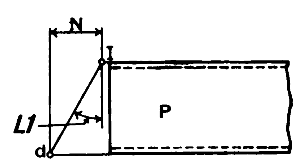
$w' = D' \tan \angle 3'$

$N = P \tan \angle 1$

$N' = P' \tan \angle 1'$







$y = D - D'$

$y_2 = y_1 \tan \angle 3'$

$w = D \tan \angle 3$

$w' = D' \tan \angle 3'$

$N = P \tan \angle 1$

$N' = P' \tan \angle 1'$

3d. Use of the graphics on pages 11, 12 and 13 expedite the work and give accurate results.

4th. A short method of graphics for solution of Angles ***L5***, ***L6*** and ***L8*** also appears on page 10, which may be used after solving ***L3*** and ***L4***, if desired.

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PURLIN WEB PLANE.

Seen in Elevation of Truss as line c, d.
Seen in Plan as inclined surface d_1, c_1, e_1.

RAFTER WEB PLANE.

Seen in Elevation of Rafter as surface r_2, c_2, b_2.
Seen in Plan as line r_1, b_1.

RAFTER FLANGE PLANE.

Seen in Elevation of Rafter as line r_2, b_2.
Seen in Plan as inclined surface r_1, b_1, e_1.

6th. Other formulae which may be used if desired are as follows:
Cos ***L3***=Cos R Cos ***L1*** Sec A.
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Tan ***L5***=Tan ***L2*** Cos ***L1***.
Tan ***L7***=Sin A Sin B Cos ***L4***.
Tan ***L7***=Cos ***L2*** Tan ***L10***.

HOPPERS, BINS AND CHUTES (FORMS OF VALLEY CONSTRUCTION).

Details for these structures are left to the judgment of the detailer and are usually governed by the main design. The solution of the bend on connecting plate at dihedral intersections is the only difficulty for most draftsmen. Both formulae and graphics are provided on page 17 for ready use.

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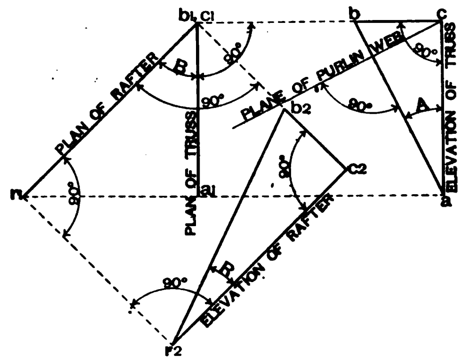
GRAPHIC SOLUTION OF ANGLES

A = PITCH OF ROOF

B = ANGLE BETWEEN TRUSS AND RAFTER IN PLAN

R = PITCH OF RAFTER

Tan R = Tan A Cos B



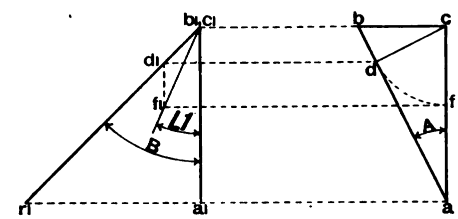
L1—BEVEL ON PURLIN WEB PLANE MADE BY INTERSECTION OF RAFTER WEB PLANE

FORMULA

Tan L_1 – Sin A Tan B

GRAPHICS

Draw d, c ⊥ a, b
Draw d, d_1 ∥ b, b_1
Revolve d to f, about c
Draw f, f_1 ∥ d, d_1
Draw d_1, f_1 ⊥ d, d_1
Connect f_1 with c_1



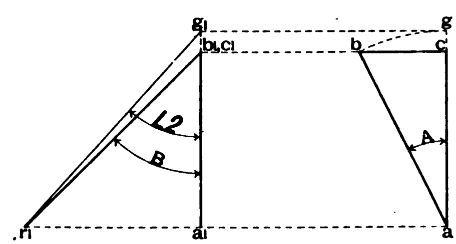
L2—BEVEL ON ROOF PLANE MADE BY INTERSECTION OF RAFTER WEB PLANE

FORMULA

Tan L_2 – Tan B Cos A

GRAPHICS

Revolve b to g about a
Draw g, g_1 ∥ b, b_1
Extend a_1, b_1 to g_1
Connect g_1 with r_1



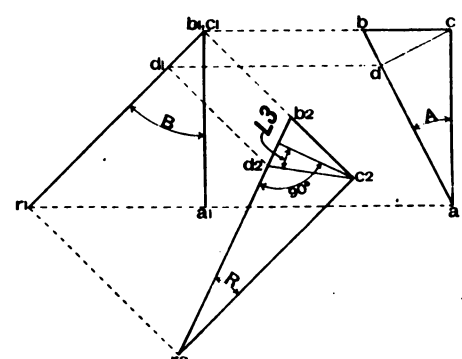
L3—BEVEL ON RAFTER WEB PLANE MADE BY INTERSECTION OF PURLIN WEB PLANE

FORMULA

Tan L_3 – Sin A Cos A Sin B Tan B

GRAPHICS

Draw d, c ⊥ a, b
Draw d, d_1 ∥ b, b_1
Draw d_1, d_2 ∥ b_1, b_2
Connect d_2 with c_2



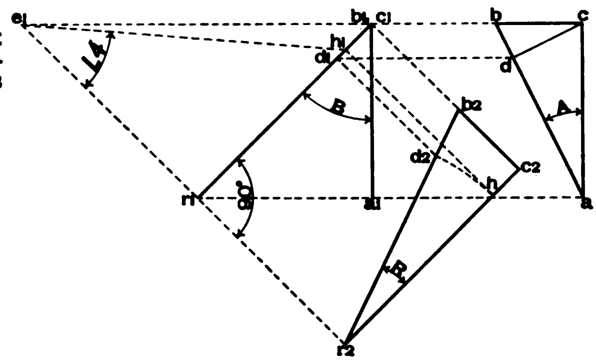
$\angle 4$—BEVEL ON RAFTER FLANGE PLANE MADE BY INTERSECTION OF PURLIN WEB PLANE

FORMULA

$\text{Tan}\,\angle 4 = \text{Cos}^2 A\ \text{Tan}\ B\ \text{Sec}\ R$

GRAPHICS

- **Draw $d, c \perp a, b$**
- **Draw $d, d_1 \parallel b, b_1$**
- **Draw $d_1, d_2 \parallel b_1, b_2$**
- **Revolve d_2 to h, about r_2**
- **Draw $h, h_1 \parallel b_1, b_2$**
- **Extend b, b_1 to intersect r_1, r_2 at e_1**
- **Connect e_1 with h_1**



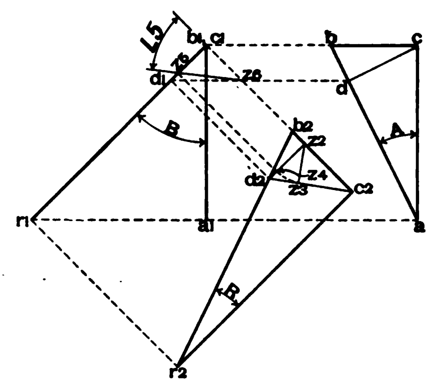
$\angle 5$—COMPLEMENT OF ANGLE BETWEEN PURLIN WEB PLANE AND RAFTER WEB PLANE

FORMULA

$\text{Tan}\,\angle 5 = \text{Cos}\,\angle 3\ \text{Tan}\,\angle 4$

GRAPHICS

- **Draw $d, c \perp a, b$**
- **Draw $d, d_1 \parallel b, b_1$**
- **Draw $d_1, d_2 \parallel b_1, b_2$**
- **Draw $d_2, z_2 \perp b_2, c_2$**
- **Draw $z_2, z_3 \perp d_2, c_2$**
- **Revolve z_3 to z_4 about z_2**
- **Draw $z_4, z_5 \parallel b_1, b_2$**
- **Locate z_6 at intersection of d, d_1 and c_1, c_2**
- **Connect z_5 with z_6**



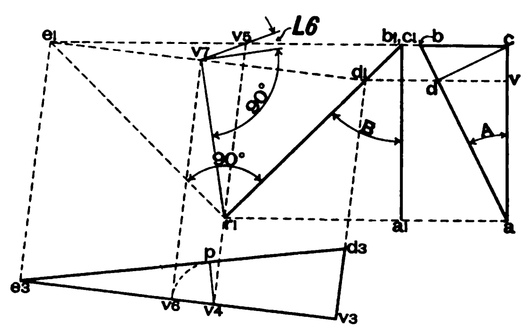
$\angle 6$—COMPLEMENT OF ANGLE BETWEEN PURLIN WEB PLANE AND RAFTER FLANGE PLANE

FORMULA

$\text{Tan}\,\angle 6 = \text{Tan}\,\angle 3\ \text{Cos}\,\angle 4$

GRAPHICS

- **Draw $d, c \perp a, b$**
- **Draw $d, d_1 \parallel b, b_1$ and extend to v**
- **Extend b, b_1 to e_1**
- **Connect e_1 with d_1**
- **Draw $e_3, v_3 \parallel e_1, d_1$**
- **Draw e_1, e_3 and $d_1, v_3 \perp e_1, d_1$**
- **Take $v_3, d_3 = d, v$**
- **Connect e_3 with d_3**
- **Through r_1, draw $v_4, v_5 \perp e_1, d_1$**
- **Draw $v_4, p \perp e_3, d_3$**
- **Revolve p to v_6 about v_4**
- **Draw $v_6, v_7 \perp e_1, d_1$**
- **Connect v_7 with r_1 and v_5**



GRAPHIC SOLUTION OF ANGLES

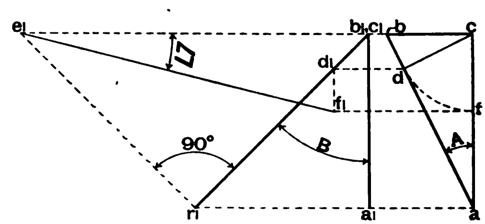
∠7—BEVEL ON PURLIN WEB PLANE MADE BY RAFTER FLANGE PLANE

FORMULA

Tan ∠7 Tan B Sin R Cos ∠2

GRAPHICS

Draw $d, c \perp a, b$
Draw $d, d_1 \parallel b, b_1$
Revolve d to f about c
Draw $f, f_1 \parallel b, b_1$
Draw $d_1, f_1 \perp d, d_1$
Extend b, b_1 to e_1
Connect e_1 with f_1



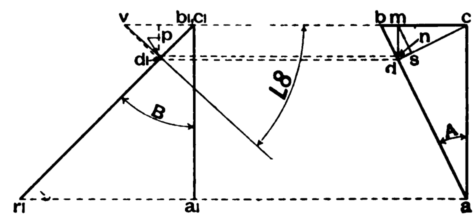
∠8—ANGLE BETWEEN PURLIN WEB PLANE AND A PLANE PERPENDICULAR TO BOTH RAFTER WEB PLANE AND RAFTER FLANGE PLANE

FORMULA

Tan ∠8 = Tan B, Cos A

GRAPHICS

Draw $d, c \perp a, b$
Draw $d, d_1 \parallel b, b_1$
Draw $d, m \perp b, c$
Draw $m, s \perp d, c$
Revolve s to n about m
Draw $n, p \parallel d, d_1$
Draw d_1 p $\perp d, d_1$
Draw $d_1, v \perp r_1, b_1$ to intersect b, b_1 at v
Connect v with p



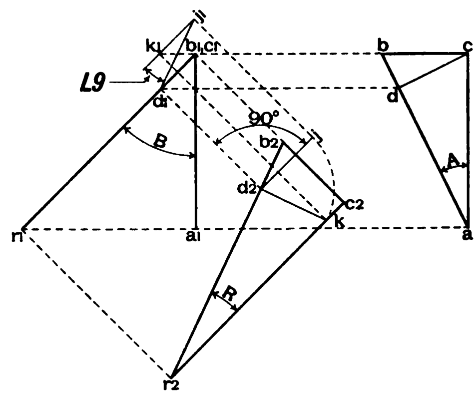
∠9—BEVEL ON PLANE PERPENDICULAR TO BOTH RAFTER WEB PLANE AND RAFTER FLANGE PLANE MADE BY INTERSECTION OF PURLIN WEB PLANE

FORMULA

Tan ∠9 = Tan B Sin R

GRAPHICS

Draw $d, c \perp a, b$
Draw $d, d_1 \parallel b, b_1$
Draw $d_1, d_2 \parallel b_1, b_2$
Draw $d_2, k \perp r_2, b_2$
Draw $k, k_1 \perp r_1, b_1$
Revolve k to j about d_2
Draw $j, j_1 \parallel k, k_1$
Draw $k_1, j_1 \perp k, k_1$
Connect d_1 with j_1



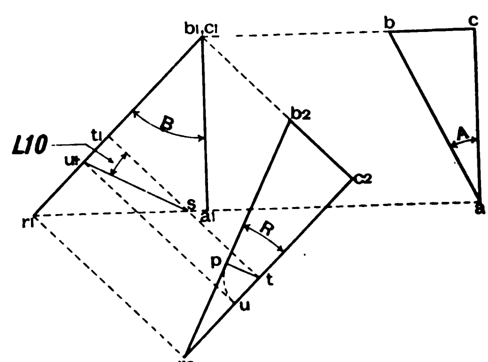
∠10—ANGLE BETWEEN ROOF PLANE AND RAFTER FLANGE PLANE

FORMULA

Tan ∠10 = Tan B Sin R

GRAPHICS

Take p any point on b_2, r_2
Draw $p, t \perp b_2, r_2$
Revolve p to u about t
Draw $t, t_1 \parallel b_1, b_2$
Draw $u, u_1 \parallel b_1, b_2$
Locate s at intersection of t, t_1 and a, r_1
Connect u_1 with s



SOLUTIONS, FIVE ORDINARY ROOF PITCHES

B=30°

A	1/5 PITCH		1/4 PITCH		30° PITCH		1/3 PITCH		55° PITCH	
	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.
R	4 5/32	9.53959	5 3/16	9.63650	6	9.69897	6 15/16	9.76144	14 27/32	0.09230
L 1	2 3/16	9.33127	3 3/32	9.41195	3 15/32	9.46041	3 27/32	9.50550	5 11/16	9.67480
L 2	6 7/16	9.72921	6 3/16	9.71298	6	9.69897	5 3/4	9.68159	3 31/32	9.52003
L 3	1 3/16	8.99801	1 13/32	9.06247	1 1/2	9.09691	1 19/32	9.12462	1 5/8	9.13237
L 4	6 5/16	9.72159	6 1/32	9.70185	5 13/16	9.68496	5 17/32	9.66421	3 5/8	9.48016
L 5	6 9/32	9.71945	6	9.69897	5 3/4	9.68159	5 1/2	9.66039	3 19/32	9.47620
L 6	1 1/16	8.94484	1 1/4	9.01344	1 11/32	9.05119	1 7/16	9.08268	1 9/16	9.11340
L 7	2	9.22157	2 7/16	9.30929	2 25/32	9.36350	3 1/8	9.41532	5 1/8	9.62961
L 8	6 7/16	9.72921	6 3/16	9.71298	6	9.69897	5 3/4	9.68159	3 31/32	9.52003
L 9	2 9/32	9.27642	2 3/4	9.36062	3 3/32	9.41195	3 15/32	9.46041	5 5/8	9.65221
L 10	2 9/32	9.27642	2 3/4	9.36062	3 3/32	9.41195	3 15/32	9.46041	5 5/8	9.65221

"S" = Corresponding Bevels or Slopes to Base of 12 inches.

A	1/5 PITCH					1/4 PITCH					30° PITCH					1/3 PITCH					55° PITCH				
X 1	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4
Y 1	9/32	15/32	9/16	13/16	1 3/16	11/32	9/16	11/16	31/32	1 7/16	3/8	21/32	25/32	1 3/32	1 5/8	7/16	23/32	7/8	1 7/32	1 13/16	11/16	1 1/8	1 11/32	1 29/32	2 13/16
Y 2	1/32	1/16	1/16	3/32	1/8	1/32	1/16	3/32	1/8	5/32	1/16	3/32	3/32	1/8	3/16	1/16	3/32	1/8	5/32	1/4	3/32	5/32	3/16	1/4	3/8
Y 3	13/16	1 3/8	1 5/8	2 5/16	3 13/32	25/32	1 5/16	1 19/32	2 1/4	3 5/16	25/32	1 9/32	1 9/16	2 3/16	3 7/32	3/4	1 1/4	1 1/2	2 1/8	3 1/8	17/32	29/32	1 3/32	1 17/32	2 9/32
Y 4	1 23/32	2 7/8	3 15/32	4 29/32	7 7/32	1 23/32	2 7/8	3 15/32	4 29/32	7 7/32	1 23/32	2 7/8	3 15/32	4 29/32	7 7/32	1 23/32	2 7/8	3 15/32	4 29/32	7 7/32	1 23/32	2 7/8	3 15/32	4 29/32	7 7/32

For Purlins not exceeding 12″ Depth, with 4½″ Connection Clearance, the following assigned values of X_2, X_3, X_4, give good Results. Y_5 to Y_{10} derived therefrom.

CLEARANCES FOR 9 INCH PURLIN

A	1/5 PITCH			1/4 PITCH			30° PITCH			1/3 PITCH			55° PITCH		
	X_2= 6½	X_3= 5	X_4= 4½	X_2= 6¾	X_3= 5	X_4= 4½	X_2= 7	X_3= 5	X_4= 4½	X_2= 7¼	X_3= 5	X_4= 4½	X_2= 8½	X_3= 5	X_4= 4½
Y 5	3 17/32	....	....	3 9/16	....	....	3 5/8	....	....	3 5/8	....	....	3 3/32	....	....
Y 6	7 1/2	....	....	7 25/32	....	....	8 3/32	....	....	8 3/8	....	....	9 13/16	....	....
Y 7	....	2 23/32	....	....	2 21/32	....	....	2 19/32	....	....	2 1/2	....	....	1 13/16	....
Y 8	....	5 25/32	....	....	5 25/32	....	....	5 25/32	....	....	5 25/32	....	....	5 25/32	....
Y 9	....	....	2 15/32	....	....	2 3/8	....	....	2 5/16	....	....	2 1/4	....	....	1 5/8
Y 10	....	....	5 3/16	....	....	5 3/16	....	....	5 3/16	....	....	5 3/16	....	....	5 3/16

CLEARANCES FOR 12 INCH PURLIN

A	1/5 PITCH			1/4 PITCH			30° PITCH			1/3 PITCH			55° PITCH		
	X_2= 7	X_3= 7½	X_4= 4½	X_2= 7½	X_3= 7½	X_4= 4½	X_2= 8	X_3= 7½	X_4= 4½	X_2= 8½	X_3= 7½	X_4= 4½	X_2= 10	X_3= 7½	X_4= 4½
Y 5	3 13/16	....	....	3 31/32	....	....	4 1/8	....	....	4 1/4	....	....	3 5/8	....	....
Y 6	8 3/32	....	....	8 21/32	....	....	9 1/4	....	....	9 13/16	....	....	11 9/16	....	....
Y 7	....	4 3/32	....	....	3 31/32	....	....	3 7/8	....	....	3 3/4	....	....	2 23/32	....
Y 8	....	8 21/32	....	....	8 21/32	....	....	8 21/32	....	....	8 21/32	....	....	8 21/32	....
Y 9	....	....	2 15/32	....	....	2 3/8	....	....	2 5/16	....	....	2 1/4	....	....	1 5/8
Y 10	....	....	5 3/16	....	....	5 3/16	....	....	5 3/16	....	....	5 3/16	....	....	5 3/16

SOLUTIONS, FIVE ORDINARY ROOF PITCHES

B = 45°

A	1/5 PITCH		1/4 PITCH		30° PITCH		1/3 PITCH		55° PITCH	
	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.
R	3 13/32	9.45154	4 1/4	9.54845	4 7/8	9.61092	5 21/32	9.67339	12 1/8	0.00426
L 1	4 15/32	9.56983	5 5/8	9.65051	6	9.69897	6 21/32	9.74406	9 27/32	9.91336
L 2	11 5/32	9.96777	10 3/4	9.95154	10 13/32	9.93753	10	9.92015	6 7/8	9.75859
L 3	2 15/16	9.38709	3 3/8	9.45154	3 11/16	9.48599	3 29/32	9.51369	4	9.52144
L 4	10 3/4	9.95225	10 5/16	9.92867	9 23/32	9.90853	9 3/16	9.88387	5 5/8	9.66984
L 5	10 7/16	9.93971	9 13/16	9.91195	9 5/16	9.88908	8 23/32	9.86190	5 5/16	9.64710
L 6	2 3/16	9.25914	2 19/32	9.33379	2 27/32	9.37641	3 1/8	9.41357	3 5/8	9.47851
L 7	2 13/32	9.29984	2 31/32	9.39524	3 7/16	9.45593	3 15/16	9.51558	7 13/32	9.78984
L 8	11 5/32	9.96777	10 3/4	9.95154	10 13/32	9.93753	10	9.92015	6 7/8	9.75859
L 9	3 1/4	9.43483	4	9.52288	4 17/32	9.57745	5 1/8	9.62982	8 17/32	9.85160
L 10	3 1/4	9.43483	4	9.52288	4 17/32	9.57745	5 1/8	9.62982	8 17/32	9.85160

"S" — Corresponding Bevels or Slopes to Base of 12 inches.

A	1/5 PITCH					1/4 PITCH					30° PITCH					1/3 PITCH					55° PITCH				
X 1	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4
Y 1	13/32	11/16	13/16	1 5/32	1 11/16	1/2	27/32	1	1 13/32	2 3/32	9/16	15/16	1 1/8	1 19/32	2 3/8	5/8	1 1/16	1 9/32	1 13/16	2 21/32	1 1/16	1 25/32	2 1/8	3 1/32	4 7/16
Y 2	5/32	5/32	3/16	9/32	13/32	5/32	1/4	9/32	13/32	19/32	3/16	9/32	11/32	1/2	23/32	7/32	11/32	13/32	19/32	7/8	11/32	19/32	23/32	1	1 15/32
Y 3	1 7/16	2 13/32	2 7/8	4 5/32	6	1 13/32	2 11/32	2 27/32	4	5 29/32	1 3/8	2 5/16	2 25/32	3 15/16	5 25/32	1 11/32	2 1/4	2 23/32	3 27/32	5 21/32	1 1/16	1 3/4	2 1/8	3	4 13/32
Y 4	2 1/8	3 17/32	4 1/4	6	8 27/32	2 1/8	3 17/32	4 1/4	6	8 27/32	2 1/8	3 17/32	4 1/4	6	8 27/32	2 1/8	3 17/32	4 1/4	6	8 27/32	2 1/8	3 17/32	4 1/4	6	8 27/32

For Purlins not exceeding 12″ Depth, with 4½″ Connection Clearance, the following assigned values of X_2, X_3, X_4 give good Results. Y_5 to Y_{10} derived therefrom.

CLEARANCES FOR 9 INCH PURLIN

A	1/5 PITCH			1/4 PITCH			30° PITCH			1/3 PITCH			55° PITCH		
	X_2= 7	X_3= 5½	X_4= 4½	X_2= 7½	X_3= 5½	X_4= 4½	X_2= 8	X_3= 5½	X_4= 4½	X_2= 8½	X_3= 5½	X_4= 4½	X_2= 10	X_3= 5½	X_4= 4½
Y 5	6 3/4			7 1/16			7 13/32			7 11/16			7 1/32		
Y 6	9 29/32			10 19/32			11 5/16			12 1/32			14 5/32		
Y 7		5 9/32			5 3/16			5 3/32			4 31/32			3 7/8	
Y 8		7 25/32			7 25/32			7 25/32			7 25/32			7 25/32	
Y 9			4 11/32			4 1/4			4 5/32			4 1/16			3 5/32
Y10			6 3/8			6 3/8			6 3/8			6 3/8			6 3/8

CLEARANCES FOR 12 INCH PURLIN

A	1/5 PITCH			1/4 PITCH			30° PITCH			1/3 PITCH			55° PITCH		
	X_2= 8	X_3= 7½	X_4= 4½	X_2= 8½	X_3= 7½	X_4= 4½	X_2= 9	X_3= 7½	X_4= 4½	X_2= 9½	X_3= 7½	X_4= 4½	X_2= 11½	X_3= 7½	X_4= 4½
Y 5	7 11/16			8			8 11/32			8 19/32			8 3/32		
Y 6	11 5/16			12 1/32			12 3/4			13 7/16			16 1/4		
Y 7		7 7/32			7 1/16			6 15/16			6 25/32			5 9/32	
Y 8		10 19/32			10 19/32			10 19/32			10 19/32			10 19/32	
Y 9			4 11/32			4 1/4			4 5/32			4 1/16			3 5/32
Y10			6 3/8			6 3/8			6 3/8			6 3/8			6 3/8

SOLUTIONS, FIVE ORDINARY ROOF PITCHES

B=50°

A	1/5 PITCH		1/4 PITCH		30° PITCH		1/3 PITCH		55° PITCH	
	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.	"S"	Log. Tan.
R	3 3/32	9.41013	3 27/32	9.50704	4 15/32	9.56951	5 5/32	9.63198	11	9.96284
L 1	5 5/16	9.64602	6 13/32	9.72670	7 9/32	9.77516	7 15/16	9.82024	11 23/32	9.98955
L 2	13 9/32	0.04396	12 25/32	0.02773	12 3/8	0.01372	11 29/32	9.99634	8 3/16	9.83478
L 3	3 25/32	9.49804	4 3/8	9.56250	4 3/4	9.59694	5 1/16	9.62465	5 5/32	9.63240
L 4	12 23/32	0.02563	12 1/32	0.00062	11 7/16	9.97927	10 25/32	9.95309	6 3/8	9.72610
L 5	12 5/32	0.00511	11 9/32	9.97344	10 5/8	9.94775	9 15/16	9.91761	5 7/8	9.68942
L 6	2 19/32	9.33433	3 3/32	9.41167	3 7/16	9.45655	3 3/4	9.49632	4 17/32	9.57824
L 7	2 3/8	9.29881	3	9.39706	3 15/32	9.46025	4	9.52286	8	9.82305
L 8	13 9/32	0.04396	12 25/32	0.02773	12 3/8	0.01372	11 29/32	9.99634	8 3/16	9.83478
L 9	3 9/16	9.47241	4 3/8	9.56188	4 31/32	9.61767	5 5/8	9.67155	9 21/32	9.90630
L 10	3 9/16	9.47241	4 3/8	9.56188	4 31/32	9.61767	5 5/8	9.67155	9 21/32	9.90630

"S"=Corresponding Bevels or Slopes to Base of 12 inches.

A	1/5 PITCH					1/4 PITCH					30° PITCH					1/3 PITCH					55° PITCH				
X 1	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4	1 1/2	2 1/2	3	4 1/4	6 1/4
Y 1	7/16	3/4	29/32	1 1/4	1 27/32	9/16	29/32	1 3/32	1 9/16	2 9/32	5/8	1 1/32	1 1/4	1 3/4	2 19/32	23/32	1 3/16	1 13/32	2	2 15/16	1 7/32	2	2 13/32	3 7/16	5 1/32
Y 2	5/32	1/4	9/32	13/32	19/32	3/16	11/32	13/32	9/16	27/32	1/4	13/32	1/2	11/16	1 1/32	5/16	1/2	19/32	27/32	1 1/4	17/32	7/8	1 1/32	1 15/32	2 5/32
Y 3	1 23/32	2 7/8	3 15/32	4 29/32	7 7/32	1 11/16	2 27/32	3 13/32	4 13/16	7 3/32	1 11/16	2 25/32	3 11/32	4 3/4	6 31/32	1 21/32	2 3/4	3 9/32	4 21/32	6 27/32	1 5/16	2 3/16	2 5/8	3 23/32	5 1/2
Y 4	2 11/32	3 7/8	4 21/32	6 5/8	9 23/32	2 11/32	3 7/8	4 21/32	6 5/8	9 23/32	2 11/32	3 7/8	4 21/32	6 5/8	9 23/32	2 11/32	3 7/8	4 21/32	6 5/8	9 23/32	2 11/32	3 7/8	4 21/32	6 5/8	9 23/32

For Purlins not exceeding 12″ Depth, with 4½″ Connection Clearance, the following assigned values of X_2, X_3, X_4, give good results. Y_5 to Y_{10} derived therefrom.

CLEARANCES FOR 9 INCH PURLIN

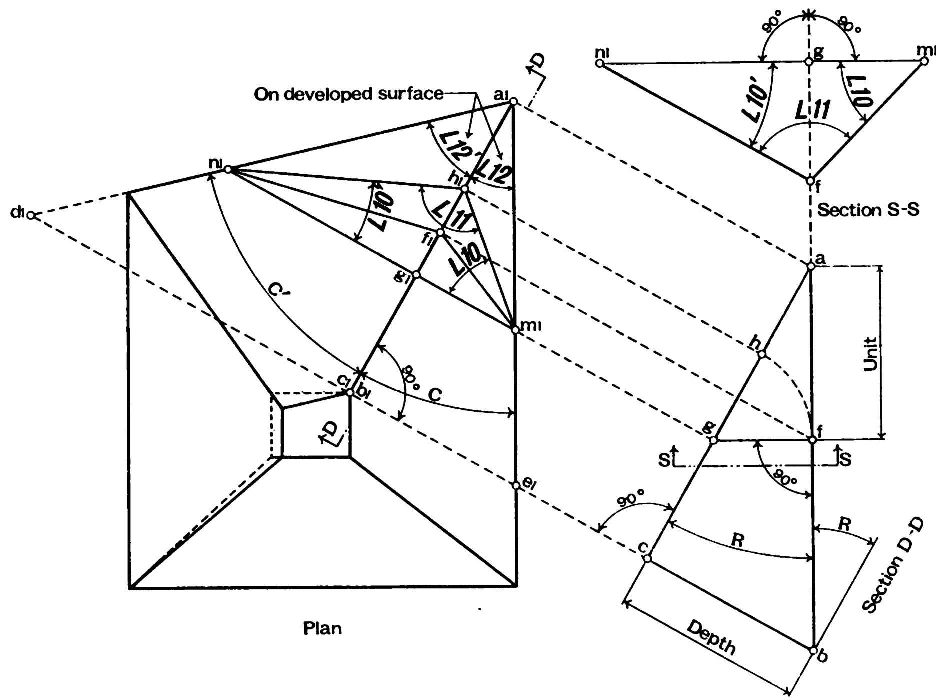
A	1/5 PITCH			1/4 PITCH			30° PITCH			1/3 PITCH			55° PITCH		
	X_2= 7½	X_3= 5½	X_4= 4½	X_2= 8	X_3= 5½	X_4= 4½	X_2= 8½	X_3= 5½	X_4= 4½	X_2= 9	X_3= 5½	X_4= 4½	X_2= 10½	X_3= 5½	X_4= 4½
Y 5	8 21/32			9 1/16			9 1/2			9 27/32			9 7/32		
Y 6	11 21/32			12 7/16			13 7/32			14			16 11/32		
Y 7		6 11/32			6 1/4			6 9/32			6 1/32			4 27/32	
Y 8		8 9/16			8 9/16			8 9/16			8 9/16			8 9/16	
Y 9			5 5/16			5 3/32			5 1/32			4 15/16			3 15/16
Y10			7			7			7			7			7

CLEARANCES FOR 12 INCH PURLIN

A	1/5 PITCH			1/4 PITCH			30° PITCH			1/3 PITCH			55° PITCH		
	X_2= 8½	X_3= 7½	X_4= 4½	X_2= 9	X_3= 7½	X_4= 4½	X_2= 9½	X_3= 7½	X_4= 4½	X_2= 10	X_3= 7½	X_4= 4½	X_2= 12½	X_3= 7½	X_4= 4½
Y 5	9 13/16			10 7/32			10 5/8			10 31/32			10 31/32		
Y 6	13 7/32			14			14 25/32			15 9/16			19 7/16		
Y 7		8 21/32			8 1/2			8 3/8			8 7/32			6 19/32	
Y 8		11 21/32			11 21/32			11 21/32			11 21/32			11 21/32	
Y 9			5 5/16			5 3/32			5 1/32			4 15/16			3 15/16
Y10			7			7			7			7			7

HOPPERS, BINS AND CHUTES

FORMULAE AND GRAPHICS FOR SOLUTION OF ANGLES



EXPLANATION

Inclined surfaces a_1, b_1, e_1, and a_1, b_1, d_1, intersect on line a_1, b_1, forming dihedral angle measured by angle *L11*. (See Section S-S.)

Vertical section a, b, c, (Section D-D) divides the dihedral into two dihedrals, of which *L10* and *L10'* are respectively the complements.

Angles R, C and C' must be determined from design.

Rectangular oottom with irregular top will produce slightly warped side surfaces, see dotted lines for this condition.

GRAPHICS

Choose any point f in line a, b
Draw f, g, ⊥ a, b
Draw g, n_1 ⊥ a, c
Project f to f_1 in plan
Draw f_1, m_1 and f_1, n_1 in plan
Then m_1, n_1, f_1 is plan of Section S-S
Revolve f to h about g
Project h to h_1 in plan
Draw h_1, m_1, and h_1, n_1
Then h_1, m_1, n_1 is true view of Section S-S

FORMULAE

$\tan L10 = \sin R \cot C$

$\tan L10' = \sin R \cot C'$

$L11 = 180° - (L10 + L10')$

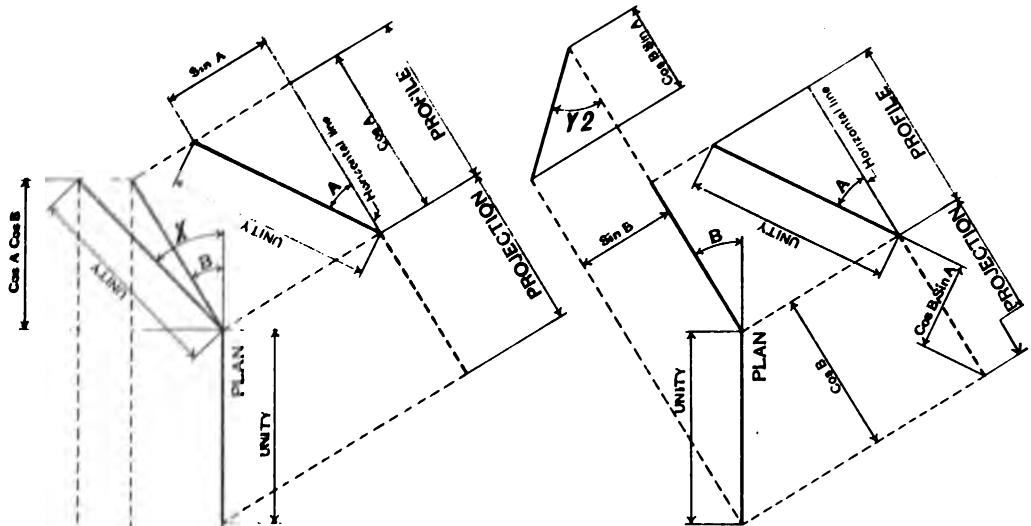
$\tan L12 = \sec R \tan C \sec L10$

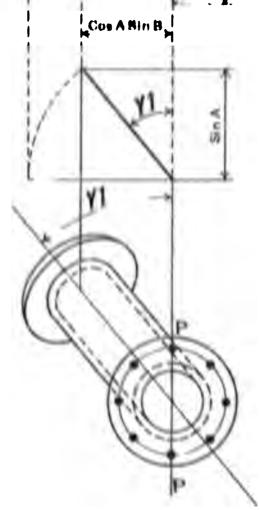
$\tan L12' = \sec R \tan C' \sec L10'$

$\cos L12 = \cos R \cos C$

$\cos L12' = \cos R \cos C'$

PIPE CONNECTION, RESULTANT OF TWO BENDS





NOTES:—

KNOWN ANGLES:—

Angle A in plane of profile

Angle B in horizontal plane or plan

THE PROFILE is the vertical section taken thru the center of the pipe line

THE LINE P-P is perpendicular to center line of pipe in plane of profile

ANGLES TO BE SOLVED:—

Resultant Angle *X*

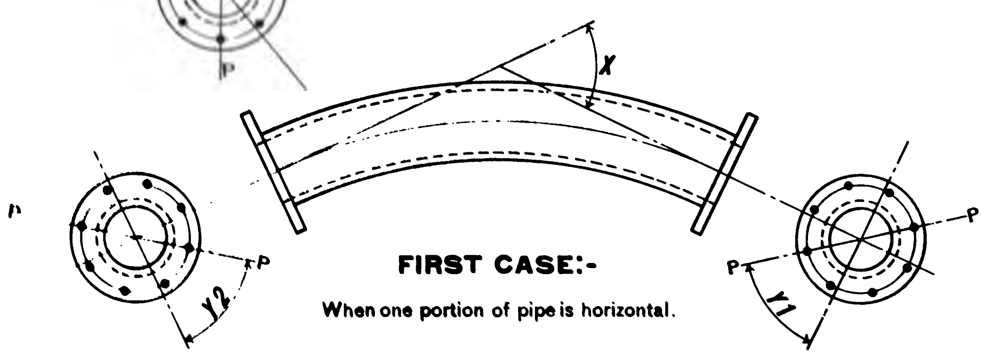
Detail Angles *Y1* and *Y2*

FORMULAE:—

$$\text{Cos } X = \text{Cos A Cos B}$$

$$\text{Tan } Y1 = \frac{\text{Cos A Sin B}}{\text{Sin A}} = \text{Cot A Sin B}$$

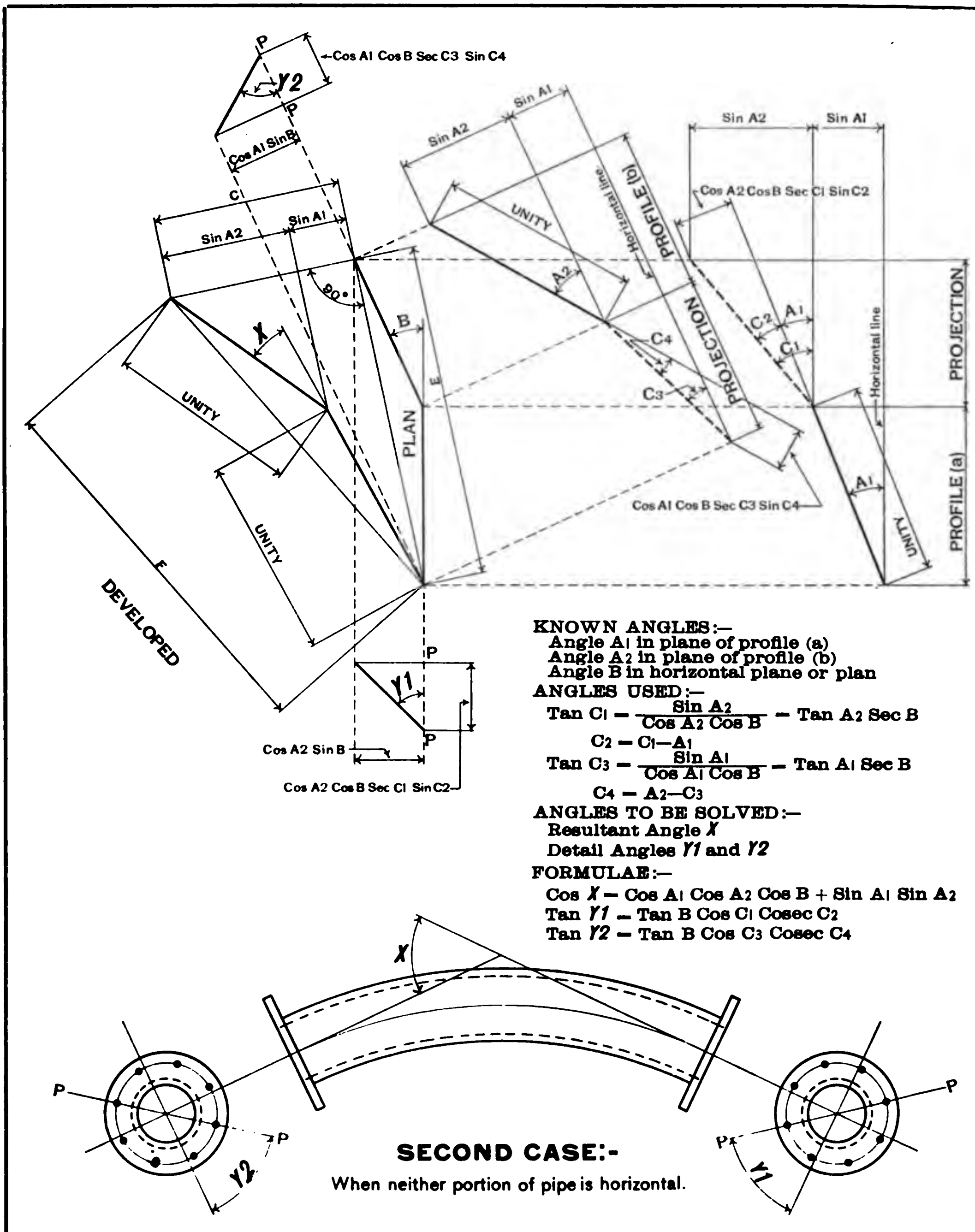
$$\text{Tan } Y2 = \frac{\text{Sin B}}{\text{Cos B Sin A}} = \text{Tan B Cosec A}$$



FIRST CASE:-

When one portion of pipe is horizontal.

PIPE CONNECTION, RESULTANT OF TWO BENDS



KNOWN ANGLES:—
Angle A_1 in plane of profile (a)
Angle A_2 in plane of profile (b)
Angle B in horizontal plane or plan

ANGLES USED:—

$$\text{Tan } C_1 = \frac{\text{Sin } A_2}{\text{Cos } A_2 \text{ Cos } B} = \text{Tan } A_2 \text{ Sec } B$$

$$C_2 = C_1 - A_1$$

$$\text{Tan } C_3 = \frac{\text{Sin } A_1}{\text{Cos } A_1 \text{ Cos } B} = \text{Tan } A_1 \text{ Sec } B$$

$$C_4 = A_2 - C_3$$

ANGLES TO BE SOLVED:—
Resultant Angle X
Detail Angles $Y1$ and $Y2$

FORMULAE:—

$$\text{Cos } X = \text{Cos } A_1 \text{ Cos } A_2 \text{ Cos } B + \text{Sin } A_1 \text{ Sin } A_2$$

$$\text{Tan } Y1 = \text{Tan } B \text{ Cos } C_1 \text{ Cosec } C_2$$

$$\text{Tan } Y2 = \text{Tan } B \text{ Cos } C_3 \text{ Cosec } C_4$$

SECOND CASE:-
When neither portion of pipe is horizontal.

ANALYTIC PROOFS

Refer to Page 10; a c = unity.

Tangent *R*

$$\text{Tan } R=\frac{c_2,\ b_2}{c_2,\ r_2}$$
$$c_2,\ b_2=c,\ b$$
$$=\text{Tan A}$$
$$c_2,\ r_2=c_1,\ r_1$$
$$=\text{Sec B}$$
$$\therefore \text{Tan R}=\frac{\text{Tan A}}{\text{Sec B}}$$
$$=\text{Tan A Cos B} \checkmark$$

Tangent *L1*

$$\text{Tan } L1=\frac{f_1,\ z_1}{f,\ c}$$
$$f_1,\ z_1=d_1,\ z_2$$
$$=(d,\ m)\ \text{Tan B}$$
$$\text{But } d,\ m=\text{Sin}^2\text{A}$$
$$\therefore f_1,\ z_1=\text{Sin}^2\text{ A Tan B}$$
$$f,\ c=d,\ c$$
$$=\text{Sin A}$$
$$\therefore \text{Tan } L1=\frac{\text{Sin}^2\text{ A Tan B}}{\text{Sin A}}$$
$$=\text{Sin A Tan B}$$

Tangent *L2*

$$\text{Tan } L2=\frac{g_1,\ z_3}{b,\ g}$$
$$g_1,\ z_3=d_1,\ z_2$$
$$=(d,\ m)\ \text{Tan B}$$
$$\text{But } d,\ m=\text{Sin}^2\text{ A}$$
$$\therefore g_1,\ z_3=\text{Sin}^2\text{ A Tan B}$$
$$b,\ g=b,\ d$$
$$=(d,\ c)\ \text{Tan A}$$
$$=\text{Sin A Tan A}$$
$$\therefore \text{Tan } L2=\frac{\text{Sin}^2\text{ A Tan B}}{\text{Sin A Tan A}}$$
$$=\frac{\text{Sin A Tan B}}{\text{Tan A}}$$
$$=\text{Cos A Tan B}$$

Tangent *L4*

$$\text{Tan } L4=\frac{r_1,\ h_1}{r_1,\ e_1}$$
$$r_1,\ h_1=r_2,\ h$$
$$=r_2,\ d_2$$
$$=\text{Cos}^2\text{ A Sec B Sec R}$$
$$r_1,\ e_1=\text{Csc B}$$
$$\therefore \text{Tan } L4=\frac{\text{Cos}^2\text{ A Sec B Sec R}}{\text{Csc B}}$$
$$=\frac{\text{Cos}^2\text{ A Sin B}}{\text{Cos B Cos R}}$$
$$=\text{Cos}^2\text{ A Tan B Sec R}$$

Tangent *L7*

$$\text{Tan } L7=\frac{f_1,k_1}{e_1,\ k_1}$$
$$f_1,\ k_1=c,\ f$$
$$=d,\ c$$
$$=\text{Sin A}$$
$$a,\ d=\text{Cos A}$$
$$r_2,\ d_2=(a,\ d)\ \text{Sec } L2$$
$$=\text{Cos A Sec } L2$$
$$r_2,\ k=(r_2,\ d_2)\ \text{Sec R}$$
$$=\text{Cos A Sec } L2 \text{ Sec R}$$
$$e_1,\ k_1=(r_2,\ k)\ \text{Csc B}$$
$$=\text{Cos A Sec } L2 \text{ Sec R Csc B}$$
$$\therefore \text{Tan } L7=\frac{\text{Sin A}}{\text{Cos A Sec } L2 \text{ Sec R Csc B}}$$
$$=\text{Tan A Cos } L2 \text{ Cos R Sin B}$$
$$=\text{Tan A}\left(\frac{\text{Sin R}}{\text{Tan R}}\right)\text{Tan B Cos B Cos} L2$$
$$=\frac{\text{Tan A Sin R Tan B Cos B Cos} L2}{\text{Tan A Cos B}}$$
$$=\text{Sin R Tan B Cos } L2$$

Tangent *L8*

$$\text{Tan } L8=\frac{n_1,\ k_1}{k_1,\ v}$$
$$n_1,\ k_1=n,\ m$$
$$=m,\ w$$
$$=(d,\ m)\ \text{Cos A}$$
$$=\text{Sin}^2\text{ A Cos A}$$
$$k_1,\ v=(d_1,\ k_1)\ \text{Cot B}$$
$$=(d,\ m)\ \text{Cot B}$$
$$=\text{Sin}^2\text{ A Cot B}$$
$$\therefore \text{Tan } L8=\frac{\text{Sin}^2\text{ A Cos A}}{\text{Sin}^2\text{ A Cot B}}$$
$$=\text{Cos A Tan B}$$

Tangent *L9*

$$\text{Tan } L9=\frac{j_1,\ z_4}{d_1,\ z_4}$$
$$d_1,\ z_4=d_2,\ j$$
$$=d_2,\ k$$
$$j_1,\ z_4=k_1,\ z_5$$
$$=(d_1,\ z_5)\ \text{Tan B}$$
$$d_1,\ z_5=(d_2,\ k)\ \text{Sin R}$$
$$\therefore j_1,\ z_4=(d_2,\ k)\ \text{Sin R Tan B}$$
$$\therefore \text{Tan } L9=\frac{(d_2,\ k)\ \text{Sin R Tan B}}{(d_2,\ k)}$$
$$=\text{Sin R Tan B}$$

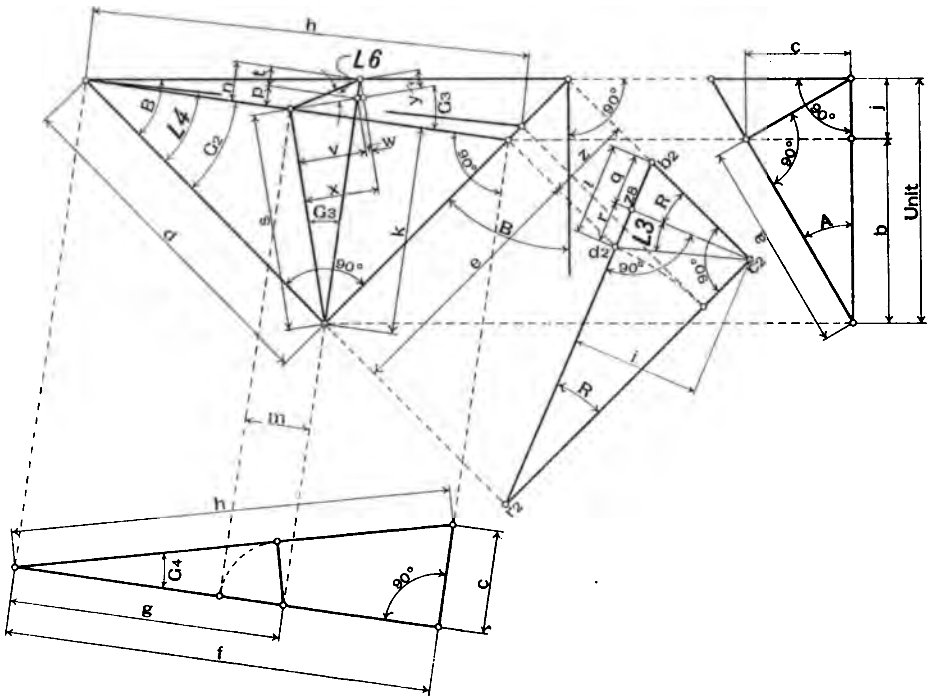
Tangent *L10*

$$\text{Tan } L10=\frac{u_1,\ t_1}{t_1,\ s_1}$$

p is any point on r_2, b_2
Choose location such that s_1 will fall at a

$$t_1,\ s_1=\text{Sin B}$$
$$t,\ r_2=t_1,\ r_1$$
$$=(r_1,\ s_1)\ \text{Sin B}$$
$$=\text{Tan B Sin B}$$
$$u_1,\ t_1=u,\ t$$
$$=p,\ t$$
$$=(t,\ r_2)\ \text{Sin R}$$
$$=\text{Tan B Sin B Sin R}$$
$$\therefore \text{Tan } L10=\frac{\text{Tan B Sin B Sin R}}{\text{Sin B}}$$
$$=\text{Tan B Sin R}$$

ANALYTIC PROOFS



Tangent $\angle 3$

1. $\text{Tan } \angle 3 = \frac{r}{l}$
2. $= \frac{l - q}{l}$
3. $j = \text{Sin}^2 A$
4. $b_2, c_2 = \text{Tan } A$
5. $z = \frac{j}{\text{Cos } B}$
6. $= \frac{\text{Sin}^2 A}{\text{Cos } B}$
7. $l = \frac{z}{\text{Cos } R}$
8. $= \frac{\text{Sin}^2 A}{\text{Cos } B \text{ Cos } R}$
9. $q = (b_2, c_2) \text{ Sin } R$
10. $= \text{Tan } A \text{ Sin } R$
11. $= \frac{\text{Sin } A \text{ Sin } R}{\text{Cos } A}$
12. $r = l - q$
13. $= \frac{\text{Sin}^2 A}{\text{Cos } B \text{ Cos } R} - \frac{\text{Sin } A \text{ Sin } R}{\text{Cos } A}$
14. $(e + z) = \frac{1}{\text{Cos } B}$
15. $i = (e + z) \text{ Sin } R$
16. $= \frac{1}{\text{Cos } B} \text{ Sin } R$
17. $= \frac{\text{Sin } R}{\text{Cos } B}$
18. $\therefore \text{Tan } \angle 3 = \frac{\frac{\text{Sin}^2 A}{\text{Cos } B \text{ Cos } R} - \frac{\text{Sin } A \text{ Sin } R}{\text{Cos } A}}{\frac{\text{Sin } R}{\text{Cos } B}}$

ANALYTIC PROOFS

19. $$=\frac{\dfrac{\sin^2 A\cos A-\sin A\sin R\cos B\cos R}{\cos B\cos R\cos A}}{\dfrac{\sin R}{\cos B}}$$

20. $$=\frac{\sin^2 A\cos A-\sin A\cos^2 R\tan R\cos B}{\cos A\cos^2 R\tan R}$$

21. $$=\frac{\sin^2 A\cos A-\sin A\cos^2 R\tan A\cos^2 B}{\cos A\cos^2 R\tan A\cos B}$$

22. $$=\frac{\cos A\sin^2 A-\dfrac{\sin^2 A\cos^2 R\cos^2 B}{\cos A}}{\dfrac{\cos A\cos^2 R\sin A\cos B}{\cos A}}$$

23. $$=\frac{\dfrac{\cos^2 A\sin^2 A-\sin^2 A\cos^2 R\cos^2 B}{\cos A}}{\dfrac{\cos A\cos^2 R\sin A\cos B}{\cos A}}$$

24. $$=\frac{\cos^2 A\sin^2 A-\sin^2 A\cos^2 R\cos^2 B}{\cos A\cos^2 R\sin A\cos B}$$

25. But, r2, b2 $$=\sqrt{\frac{1}{\cos^2 B}+\tan^2 A}$$

26. $$=\sqrt{\frac{1}{\cos^2 B}+\frac{\sin^2 A}{\cos^2 A}}$$

27. $$=\sqrt{\frac{\cos^2 A+\sin^2 A\cos^2 B}{\cos^2 A\cos^2 B}}$$

28. $$=\frac{\sqrt{\sin^2 A\cos^2 B+\cos^2 A}}{\cos A\cos B}$$

29. $$\cos R=\frac{\dfrac{1}{\cos B}}{\dfrac{\sqrt{\sin^2 A\cos^2 B+\cos^2 A}}{\cos A\cos B}}$$

30. $$=\frac{\cos A}{\sqrt{\sin^2 A\cos^2 B+\cos^2 A}}$$

Hence by substitution in No. 24.

31. $$\tan\angle 3=\frac{\sin^2 A\cos^2 A-\sin^2 A\left(\dfrac{\cos^2 A}{\sin^2 A\cos^2 B+\cos^2 A}\right)\cos^2 B}{\cos A\left(\dfrac{\cos^2 A}{\sin^2 A\cos^2 B+\cos^2 A}\right)\sin A\cos B}$$

32. $$=\frac{\dfrac{\sin^2 A\cos^2 A(\sin^2 A\cos^2 B+\cos^2 A)-\sin^2 A\cos^2 A\cos^2 B}{\sin^2 A\cos^2 B+\cos^2 A}}{\dfrac{\cos^3 A\sin A\cos B}{\sin^2 A\cos^2 B+\cos^2 A}}$$

33. $$=\frac{\sin A(\sin^2 A\cos^2 B+\cos^2 A)-\sin A\cos^2 B}{\cos A\cos B}$$

34. $$=\frac{\sin A(\sin^2 A\cos^2 B+\cos^2 A-\cos^2 B)}{\cos A\cos B}$$

35. $$=\frac{\sin A\,[\cos^2 B(\sin^2 A-1)+\cos^2 A]}{\cos A\cos B}$$

36. $$=\frac{\sin A\,[\cos^2 B(-\cos^2 A)+\cos^2 A]}{\cos A\cos B}$$

37. $$=\frac{\sin A(\cos^2 A-\cos^2 A\cos^2 B)}{\cos A\cos B}$$

38. $$=\frac{\sin A\cos^2 A(1-\cos^2 B)}{\cos A\cos B}$$

39. $$=\frac{\sin A\cos^2 A\sin^2 B}{\cos A\cos B}$$

40. $$=\sin A\cos A\sin B\tan B$$

Tangent $\angle 6$—Refer to Page 22.

1. $a=\text{Cos } A$
2. $b=\text{Cos}^2 A$
3. $c=\text{Cos } A \text{ Sin } A$
4. $d=\dfrac{1}{\text{Sin } B}$
5. $e=\dfrac{\text{Cos}^2 A}{\text{Cos } B}$
6. $f=\sqrt{d^2+e^2}$
7. $=\dfrac{\sqrt{\text{Sin}^2 B \text{ Cos}^4 A+\text{Cos}^2 B}}{\text{Cos } B \text{ Sin } B}$
8. Let $M=\sqrt{\text{Cos}^2 B+\text{Cos}^4 A \text{ Sin}^2 B}$ (for convenience)
9. Then $f=\dfrac{M}{\text{Cos } B \text{ Sin } B}$
10. $h=\sqrt{c^2+f^2}$
11. $=\sqrt{\text{Cos}^2 A \text{ Sin}^2 A+\dfrac{\text{Sin}^2 B \text{ Cos}^4 A+\text{Cos}^2 B}{\text{Cos}^2 B \text{ Sin}^2 B}}$
12. $=\dfrac{\sqrt{\text{Cos}^2 A \text{ Sin}^2 A \text{ Cos}^2 B \text{ Sin}^2 B+\text{Sin}^2 B \text{ Cos}^4 A+\text{Cos}^2 B}}{\text{Cos } B \text{ Sin } B}$
13. Let $P=\sqrt{\text{Cos}^2 A \text{ Sin}^2 A \text{ Cos}^2 B \text{ Sin}^2 B+\text{Sin}^2 B \text{ Cos}^4 A+\text{Cos}^2 B}$
14. Then $h=\dfrac{P}{\text{Cos } B \text{ Sin } B}$
15. $\text{Sin } G_4=\dfrac{c}{h}$
16. $=\dfrac{\text{Cos } A \text{ Sin } A \text{ Cos } B \text{ Sin } B}{P}$
17. $\text{Sin } G_2=\dfrac{e}{f}$
18. $=\dfrac{\dfrac{\text{Cos}^2 A}{\text{Cos } B}}{\dfrac{M}{\text{Cos } B \text{ Sin } B}}$
19. $=\dfrac{\text{Cos}^2 A \text{ Sin } B}{M}$
20. $\text{Cos } G_2=\dfrac{d}{f}$
21. $=\dfrac{\dfrac{1}{\text{Sin } B}}{\dfrac{M}{\text{Cos } B \text{ Sin } B}}$
22. $=\dfrac{\text{Cos } B}{M}$
23. $g=d \text{ Cos } G_2$

ANALYTIC PROOFS

24. $$=\left(\frac{1}{\text{Sin B}}\right)\left(\frac{\text{Cos B}}{\text{M}}\right)$$

25. $$=\frac{\text{Cos B}}{\text{M Sin B}}$$

26. $$\text{m}=\text{g Sin G}_4$$

27. $$=\left(\frac{\text{Cos B}}{\text{M Sin B}}\right)\left(\frac{\text{Cos A Sin A Cos B Sin B}}{\text{P}}\right)$$

28. $$=\frac{\text{Cos A Sin A Cos}^2\text{B}}{\text{MP}}$$

29. $$\text{k}=\text{d Sin G}_2$$

30. $$=\left(\frac{1}{\text{Sin B}}\right)\left(\frac{\text{Cos}^2\text{A Sin B}}{\text{M}}\right)$$

31. $$=\frac{\text{Cos}^2\text{A}}{\text{M}}$$

32. $$\text{s}=\sqrt{\text{k}^2+\text{m}^2}$$

33. $$=\sqrt{\left(\frac{\text{Cos}^2\text{A}}{\text{M}}\right)^2+\left(\frac{\text{Cos A Sin A Cos}^2\text{B}}{\text{MP}}\right)^2}$$

34. $$=\frac{\text{Cos A}}{\text{M P}}\sqrt{\text{P}^2\text{Cos}^2\text{A}+\text{Cos}^4\text{B Sin}^2\text{A}}$$

35. Let $\text{N}=\sqrt{\text{P}^2\text{Cos}^2\text{A}+\text{Cos}^4\text{B Sin}^2\text{A}}$ (for convenience)

36. Then $\text{s}=\frac{\text{N Cos A}}{\text{MP}}$

37. $$\text{Sin G}_3=\frac{\text{m}}{\text{s}}$$

38. $$=\frac{\frac{\text{Cos A Sin A Cos}^2\text{B}}{\text{M P}}}{\frac{\text{N Cos A}}{\text{MP}}}$$

39. $$=\frac{\text{Sin A Cos}^2\text{B}}{\text{N}}$$

40. $$\text{Cos G}_3=\frac{\text{k}}{\text{s}}$$

41. $$=\frac{\frac{\text{Cos}^2\text{A}}{\text{M}}}{\frac{\text{N Cos A}}{\text{M P}}}$$

42. $$=\frac{\text{P Cos A}}{\text{N}}$$

43. $$\text{n}=\text{g Tan (B}-\text{G}_2)$$

44. $$=\left(\frac{\text{Cos B}}{\text{M Sin B}}\right)\text{Tan (B}-\text{G}_2)$$

45. $$=\frac{\text{Cos B Sin (B}-\text{G}_2)}{\text{M Sin B Cos (B}-\text{G}_2)}$$

46. $$=\frac{\text{Cos B (Sin B Cos G}_2-\text{Cos B Sin G}_2)}{\text{M Sin B (Cos B Cos G}_2+\text{Sin B Sin G}_2)}$$

ANALYTIC PROOFS

47. $$=\frac{\text{Cos B}\left(\frac{\text{Sin B Cos B}}{\text{M}}-\frac{\text{Cos B Cos}^2\text{A Sin B}}{\text{M}}\right)}{\text{M Sin B}\left(\frac{\text{Cos}^2\text{B}}{\text{M}}+\frac{\text{Cos}^2\text{A Sin}^2\text{B}}{\text{M}}\right)}$$

48. $$=\frac{\text{Cos B (Sin B Cos B}-\text{Cos B Cos}^2\text{A Sin B)}}{\text{M Sin B (Cos}^2\text{B}+\text{Cos}^2\text{A Sin}^2\text{B)}}$$

49. $$=\frac{\text{Cos B (Cos B}-\text{Cos B Cos}^2\text{A)}}{\text{M (Cos}^2\text{B}+\text{Cos}^2\text{A Sin}^2\text{B)}}$$

50. $$=\frac{\text{Cos}^2\text{B (1}-\text{Cos}^2\text{A)}}{\text{M (Cos}^2\text{B}+\text{Cos}^2\text{A Sin}^2\text{B)}}$$

51. $$=\frac{\text{Cos}^2\text{B Sin}^2\text{A}}{\text{M (Cos}^2\text{B}+\text{Cos}^2\text{A Sin}^2\text{B)}}$$

52. $p=m \text{ Tan } G_8$

53. $t=n-p$

54. $=n-m \text{ Tan } G_8$

55. $y=t \text{ Cos } G_8$

56. $=(n-m \text{ Tan } G_8) \text{ Cos } G_8$

57. $v=\frac{m}{\text{Cos } G_8}$

58. $w=t \text{ Sin } G_8$

59. $=(n-m \text{ Tan } G_8) \text{ Sin } G_8$

60. $x=v+w$

61. $=\frac{m}{\text{Cos } G_8}+(n-m \text{ Tan } G_8) \text{ Sin } G_8$

Statement for reduction

62. $\text{Tan } \angle 6=\frac{y}{x}$

63. $$=\frac{(n-m \text{ Tan } G_8)(\text{Cos } G_8)}{\frac{m}{\text{Cos } G_8}+(n-m \text{ Tan } G_8) \text{ Sin } G_8}$$

64. $$=\frac{(n-m \text{ Tan } G_8) \text{ Cos}^2 G_8}{m+(n-m \text{ Tan } G_8) \text{ Sin } G_8 \text{ Cos } G_8}$$

65. $$=\frac{\left(n-m \frac{\text{Sin } G_8}{\text{Cos } G_8}\right) \text{Cos}^2 G_8}{m+\left(n-m \frac{\text{Sin } G_8}{\text{Cos } G_8}\right) \text{Sin } G_8 \text{ Cos } G_8}$$

66. $$=\frac{(n \text{ Cos } G_8-m \text{ Sin } G_8) \text{ Cos } G_8}{m+(n \text{ Cos } G_8-m \text{ Sin } G_8) \text{ Sin } G_8}$$

67. $$=\frac{n \text{ Cos}^2 G_8-m \text{ Sin } G_8 \text{ Cos } G_8}{m+n \text{ Cos } G_8 \text{ Sin } G_8-m \text{ Sin}^2 G_8}$$

68. $$=\frac{n \text{ Cos}^2 G_8-m \text{ Sin } G_8 \text{ Cos } G_8}{m(1-\text{Sin}^2 G_8)+n \text{ Cos } G_8 \text{ Sin } G_8}$$

69. $$=\frac{n \text{ Cos}^2 G_8-m \text{ Sin } G_8 \text{ Cos } G_8}{m \text{ Cos}^2 G_8+n \text{ Cos } G_8 \text{ Sin } G_8}$$

70. $$=\frac{n \mathrm{Cos}\, G_8 - m \mathrm{Sin}\, G_8}{m \mathrm{Cos}\, G_8 + n \mathrm{Sin}\, G_8}$$

Hence by substitution

71. $$\mathrm{Tan}\,\angle 6=\frac{\left(\frac{\mathrm{Cos}^2B\ \mathrm{Sin}^2A}{M(\mathrm{Cos}^2B+\mathrm{Cos}^2A\,\mathrm{Sin}^2B)}\right)\left(\frac{P\ \mathrm{Cos}\ A}{N}\right)-\left(\frac{\mathrm{Cos}\ A\ \mathrm{Sin}\ A\ \mathrm{Cos}^2B}{M\ P}\right)\left(\frac{\mathrm{Sin}\ A\ \mathrm{Cos}^2B}{N}\right)}{\left(\frac{\mathrm{Cos}\ A\ \mathrm{Sin}\ A\ \mathrm{Cos}^2B}{M\ P}\right)\left(\frac{P\ \mathrm{Cos}\ A}{N}\right)+\left(\frac{\mathrm{Cos}^2B\ \mathrm{Sin}^2A}{M(\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)}\right)\left(\frac{\mathrm{Sin}\ A\ \mathrm{Cos}^2B}{N}\right)}$$

72. $$=\frac{\frac{P\ \mathrm{Cos}^2B\ \mathrm{Sin}^2A\ \mathrm{Cos}\ A}{MN(\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)}-\frac{\mathrm{Cos}\ A\ \mathrm{Sin}^2A\ \mathrm{Cos}^4B}{M\ P\ N}}{\frac{P\ \mathrm{Cos}^2A\ \mathrm{Sin}\ A\ \mathrm{Cos}^2B}{M\ P\ N}+\frac{\mathrm{Cos}^4B\ \mathrm{Sin}^3A}{MN(\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)}}$$

73. $$=\frac{P^2\mathrm{Cos}\ A\ \mathrm{Cos}^2B\ \mathrm{Sin}^2A-\mathrm{Cos}^4B\ \mathrm{Sin}^2A\ \mathrm{Cos}\ A\ (\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)}{P\ \mathrm{Cos}^2A\ \mathrm{Cos}^2B\ \mathrm{Sin}\ A(\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)+P\ \mathrm{Cos}^4B\ \mathrm{Sin}^3A}$$

74. $$=\frac{\mathrm{Sin}^2A\ \mathrm{Cos}^2B\ \mathrm{Cos}\ A\ [P^2-\mathrm{Cos}^2B(\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)]}{P\ \mathrm{Sin}\ A\ \mathrm{Cos}^2B\ [\mathrm{Cos}^2A(\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)+\mathrm{Cos}\ B\ \mathrm{Sin}^2A]}$$

75. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ [P^2-\mathrm{Cos}^2B\ (\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)]}{P\ [\mathrm{Cos}^2A\ \mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}\ B+\mathrm{Cos}^2B\ \mathrm{Sin}^2A]}$$

76. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ [P^2-\mathrm{Cos}^2B\ (\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)]}{P\ [\mathrm{Cos}^2B\ (\mathrm{Cos}^2A+\mathrm{Sin}^2A)+\mathrm{Cos}^4A\ \mathrm{Sin}^2B]}$$

77. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ [P^2-\mathrm{Cos}^2B(\mathrm{Cos}^2B+\mathrm{Cos}^2A\ \mathrm{Sin}^2B)]}{P\ [\mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}^2B]}$$

78. $$\mathrm{Cos}\ \angle 4=\frac{d}{h}$$

79. $$=\frac{\frac{1}{\mathrm{Sin}\ B}}{\frac{P}{\mathrm{Sin}\ B\ \mathrm{Cos}\ B}}$$

80. $$=\frac{\mathrm{Cos}\ B}{P}$$

81. $\therefore P\ \mathrm{Cos}\ \angle 4=\mathrm{Cos}\ B$

82. $$P=\frac{\mathrm{Cos}\ B}{\mathrm{Cos}\ \angle 4}$$

83. $$P^2=\mathrm{Cos}^2A\ \mathrm{Sin}^2A\ \mathrm{Cos}^2B\ \mathrm{Sin}^2B+\mathrm{Sin}^2B\ \mathrm{Cos}^4A+\mathrm{Cos}^2B$$

84. $$\mathrm{Tan}\,\angle 6=\frac{\mathrm{Sin} A \mathrm{Cos}\ A \mathrm{Cos} \angle 4[\mathrm{Cos}^2A\,\mathrm{Sin}^2A\,\mathrm{Cos}^2B\,\mathrm{Sin}^2B+\mathrm{Sin}^2B\,\mathrm{Cos}^4A+\mathrm{Cos}^2B-\mathrm{Cos}^4B-\mathrm{Cos}^2B\mathrm{Sin}^2B\ \mathrm{Cos}^2A]}{\mathrm{Cos}\ B\ [\mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}^2B]}$$

85. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Cos}\ \angle 4\ [\mathrm{Sin}^2B\ \mathrm{Cos}^2B\ \mathrm{Cos}^2A\ (\mathrm{Sin}^2A-1)+\mathrm{Cos}^2B\ (1-\mathrm{Cos}^2B)+\mathrm{Sin}^2B\ \mathrm{Cos}^4A]}{\mathrm{Cos}\ B\ [\mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}^2B]}$$

86. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Cos}\ \angle 4\ [-\mathrm{Cos}^4A\ \mathrm{Sin}^2B\ \mathrm{Cos}^2B+\mathrm{Cos}^2B\ \mathrm{Sin}^2B+\mathrm{Sin}^2B\ \mathrm{Cos}^4A]}{\mathrm{Cos}\ B\ [\mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}^2B]}$$

87. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Cos}\ \angle 4\ [\mathrm{Cos}^4A\ \mathrm{Sin}^2B\ (1-\mathrm{Cos}^2B)+\mathrm{Cos}^2B\ \mathrm{Sin}^2B]}{\mathrm{Cos}\ B\ (\mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}^2B)}$$

88. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Cos}\ \angle 4(\mathrm{Cos}^4A\ \mathrm{Sin}^4B+\mathrm{Cos}^2B\ \mathrm{Sin}^2B)}{\mathrm{Cos}\ B\ (\mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}^2B)}$$

89. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Cos}\ \angle 4\ \mathrm{Sin}^2B\ (\mathrm{Cos}^4A\ \mathrm{Sin}^2B+\mathrm{Cos}^2B)}{\mathrm{Cos}\ B\ (\mathrm{Cos}^2B+\mathrm{Cos}^4A\ \mathrm{Sin}^2B)}$$

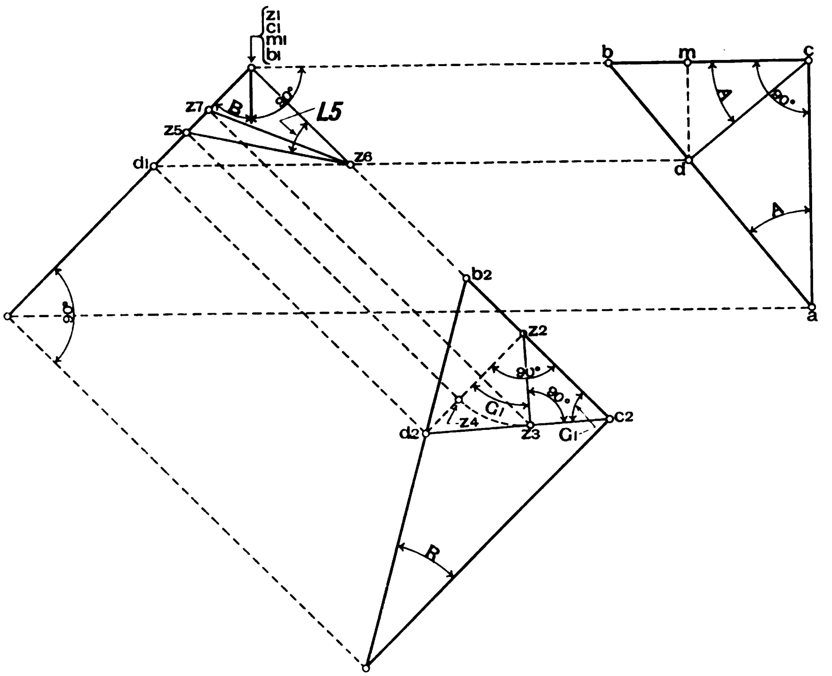
90. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Cos}\ \angle 4\ \mathrm{Sin}^2B}{\mathrm{Cos}\ B}$$

91. But, $\mathrm{Tan}\ \angle 3=\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Sin}\ B\ \mathrm{Tan}\ B$

92. $$=\frac{\mathrm{Sin}\ A\ \mathrm{Cos}\ A\ \mathrm{Sin}^2B}{\mathrm{Cos}\ B}$$

93. $\therefore\ \mathrm{Tan}\ \angle 6=\mathrm{Cos}\ \angle 4\ \mathrm{Tan}\ \angle 3$

ANALYTIC PROOFS

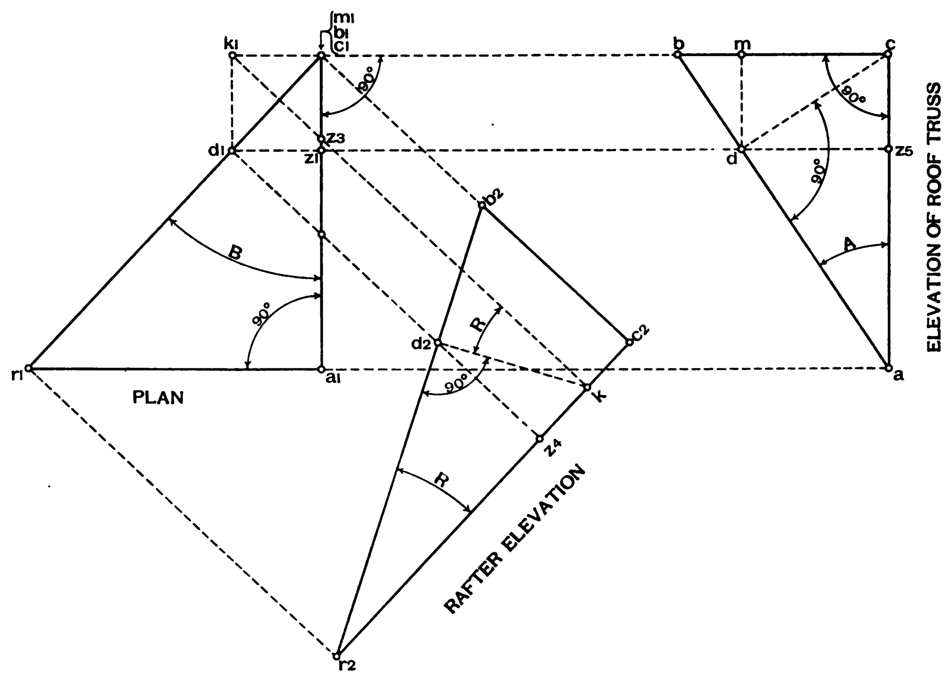


Tangent $\angle 5$

Draw $d_2, z_2 \perp b_2, c_2$
Pass a plane thru $z_2 \perp d_2, c_2$
This plane seen in plan view appears as surface z_2, z_6, z_7
Revolve this plane about z_2, z_6 to z_4
This plane then seen in plan view appears as surface z_2, z_6, z_5

1. $\text{Tan } \angle 5 = \dfrac{z_1, z_5}{z_1, z_6}$
2. $z_1, z_5 = z_2, z_3$
3. $= (z_2, d_2) \text{ Cos } G_1$
4. $= (m_1, d_1) \text{ Cos } G_1$
5. $= (d, m) \text{ Sec B Cos } G_1$
6. $= \text{Sin}^2\text{A Sec B Cos } G_1$
7. $z_1, z_6 = (d, m) \text{ Csc B}$
8. $= \text{Sin}^2\text{A Csc B}$
9. $\therefore \text{Tan } \angle 5 = \dfrac{\text{Sin}^2\text{A Sec B Cos } G_1}{\text{Sin}^2\text{A Csc B}}$
10. $= \dfrac{\text{Sin B Cos } G_1}{\text{Cos B}}$
11. $= \text{Tan B Cos } G_1$
12. $\text{But Cos } G_1 = \dfrac{c_2, z_2}{c_2, d_2}$
13. $= \dfrac{m, c}{f_1, c_1}$ (See Page 10)
14. $= \dfrac{\text{Sin A Cos A}}{f, c \text{ Sec } \angle 1}$
15. $= \dfrac{\text{Sin A Cos A}}{\text{Sin A Sec } \angle 1}$
16. $= \text{Cos A Cos } \angle 1$
17. Hence $\text{Tan } \angle 5 = \text{Tan B Cos A Cos } \angle 1$
18. $\text{But Cos } \angle 3 = \dfrac{c_2, z_8}{c_2, d_2}$
19. $c_2, z_8 = c_2, r_2 \text{ Sin R}$
20. $= \dfrac{\text{Sin R}}{\text{Cos B}}$
21. $c_2, d_2 = \text{Sin A Sec } \angle 1$
22. $\therefore \text{Cos } \angle 3 = \dfrac{\dfrac{\text{Sin R}}{\text{Cos B}}}{\dfrac{\text{Sin A}}{\text{Cos } \angle 1}}$
23. $= \dfrac{\text{Sin R Cos } \angle 1}{\text{Sin A Cos B}}$
24. And $\text{Tan } \angle 4 = \text{Cos}^2\text{A Tan B Sec R}$
25. $\text{Cos } \angle 3 \text{ Tan } \angle 4 = \left(\dfrac{\text{Sin R Cos } \angle 1}{\text{Sin A Cos B}}\right)\left(\dfrac{\text{Cos}^2\text{A Tan B}}{\text{Cos R}}\right)$
26. $= \dfrac{\text{Tan R Cos } \angle 1 \text{ Cos}^2\text{A Tan B}}{\text{Sin A Cos B}}$
27. $= \dfrac{\text{Tan A Cos B Cos } \angle 1 \text{ Cos}^2\text{A Tan B}}{\text{Sin A Cos B}}$
28. $= \dfrac{\text{Sin A Cos B Cos } \angle 1 \text{ Cos}^2\text{A Tan B}}{\text{Cos A Sin A Cos B}}$
29. $= \text{Cos A Tan B Cos } \angle 1$
30. $\therefore \text{Tan } \angle 5 = \text{Cos } \angle 3 \text{ Tan } \angle 4$

PROOF FOR THE 90° USED IN STYLES C AND D



EXPLANATION FOR 90° BEND LINE ON STYLES C AND D.

Purlin Web Plane seen from Elevation of Main Roof is Line cd.
" " " " in Plan View is Inclined Surface d_1, z_1, c_1, k_1.
Rafter Lug Plane seen in Rafter Elevation is Line d_2, k.
" " " " " Plan View is Inclined Surface d_1, z_3, k_1.
These Two Planes produced intersect on Line d_1, k_1.
Hence if k_1, c_1 equals in length d_1, z_1, then will angle k_1, d_1, z_1 be 90° in all cases.

STATEMENT OF VALUES.

ac = Unity
$cd = \sin A$
$ad = \cos A$
$z_1, a_1 = \cos^2 A$
$z_1, m_1 = \sin^2 A$
$d_1, m_1 = \sin^2 A \sec B$
$z_1, d_1 = \sin^2 A \tan B$
$d_1, r_1, r_2, z_4 = \cos^2 A \sec B$
$d_2, r_2 = \cos^2 A \sec B \sec R$
$d_2, z_4 = d, z_5 = \cos A \sin A$
$z_4, k = \cos A \sin A \tan R$
$d_2, b_2 = \sin^2 A \sec B \sec R$
$k, c_2 = \sin^2 A \sec B - \cos A \sin A \tan R$
$k_1, c_1 = (k, c_2) \csc B$

$= [\sin^2 A \sec B - \cos A \sin A \tan R] \csc B$

PROOF.

1. $(\sin^2 A \sec B - \cos A \sin A \tan R) \csc B = \sin^2 A \tan B$
2. $\dfrac{\dfrac{\sin^2 A}{\cos B} - \cos A \sin A \tan R}{\sin B} = \sin^2 A \tan B$
3. $\dfrac{\sin^2 A - \cos A \sin A \cos B \tan R}{\cos B \sin B} = \sin^2 A \tan B$
4. $\sin^2 A - \cos A \sin A \cos B \tan R = \sin^2 A \tan B \cos B \sin B$
5. $\sin^2 A - \cos A \sin A \cos B \tan R = \sin^2 A \sin^2 B$
6. $\tan R = \tan A \cos B.$
7. $\sin^2 A - \cos A \sin A \cos B \tan A \cos B = \sin^2 A \sin^2 B.$
8. $\sin^2 A - \dfrac{\cos A \sin A \cos^2 B \sin A}{\cos A} = \sin^2 A \sin^2 B$
9. $\sin^2 A - \sin^2 A \cos^2 B = \sin^2 A \sin^2 B$
10. $1 - \cos^2 B = \sin^2 B$
11. $1 = \sin^2 B + \cos^2 B$ or $1 = 1$

Hence Eq. 11 being true, proves Eq. 1 to be true.

ANALYTIC PROOF OF ANGLE X

SECOND CASE OF PIPE LINE

$$\tfrac{1}{2}F = \text{Cos}\,\frac{X}{2} \qquad\qquad \text{Cos}\,X = 2\,\text{Cos}^2\frac{X}{2} - 1$$

$$F = \sqrt{C^2 + E^2}$$

$$C = \text{Sin}\,A1 + \text{Sin}\,A_2$$

$$E = \sqrt{(\text{Cos}\,A1 + \text{Cos}\,A_2\,\text{Cos}\,B)^2 + (\text{Cos}\,A_2\,\text{Sin}\,B)^2}$$

$$F = \sqrt{(\text{Sin}\,A1 + \text{Sin}\,A_2)^2 + (\text{Cos}\,A1 + \text{Cos}\,A_2\,\text{Cos}\,B)^2 + (\text{Cos}\,A_2\,\text{Sin}\,B)^2}$$

$$= \sqrt{(\text{Sin}^2A1 + 2\,\text{Sin}\,A1\,\text{Sin}\,A_2 + \text{Sin}^2A_2) + (\text{Cos}^2A1 + 2\,\text{Cos}A1\,\text{Cos}A_2\,\text{Cos}B + \text{Cos}^2A_2\,\text{Cos}^2B) + (\text{Cos}^2A_2\,\text{Sin}^2B)}$$

$$= \sqrt{\text{Sin}^2A1 + \text{Cos}^2A1 + \text{Cos}^2A_2(\text{Sin}^2B + \text{Cos}^2B) + \text{Sin}^2A_2 + 2\,\text{Cos}\,A1\,\text{Cos}A_2\,\text{Cos}\,B + 2\,\text{Sin}A1\,\text{Sin}\,A_2}$$

$$= \sqrt{1 + \text{Cos}^2A_2(1) + \text{Sin}^2A_2 + 2\,\text{Cos}\,A1\,\text{Cos}\,A_2\,\text{Cos}\,B + 2\,\text{Sin}\,A1\,\text{Sin}\,A_2}$$

$$= \sqrt{2 + 2\,\text{Cos}\,A1\,\text{Cos}\,A_2\,\text{Cos}\,B + 2\,\text{Sin}\,A1\,\text{Sin}\,A_2}$$

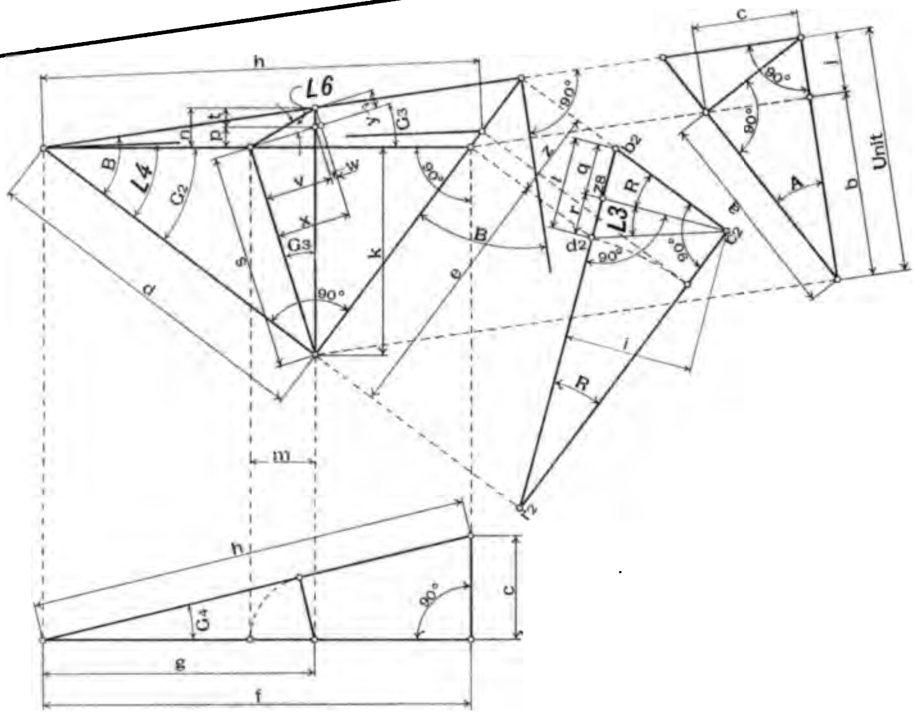
$$\text{Cos}\,\frac{X}{2} = \tfrac{1}{2}\sqrt{2 + 2\,\text{Cos}\,A1\,\text{Cos}\,A_2\,\text{Cos}\,B + 2\,\text{Sin}\,A1\,\text{Sin}\,A_2}$$

$$\text{Cos}X = \frac{2(2 + 2\,\text{Cos}\,A1\,\text{Cos}\,A_2\,\text{Cos}\,B + 2\,\text{Sin}\,A1\,\text{Sin}\,A_2)}{4} - 1$$

$$= \text{Cos}\,A1\,\text{Cos}\,A_2\,\text{Cos}\,B + \text{Sin}\,A1\,\text{Sin}\,A_2$$

When
$A1$ or $A_2 = 0$
above formula becomes
$\text{Cos}\,X = \text{Cos}\,A\,\text{Cos}\,B$
which is same as first case

ANALYTIC PROOFS



Tangent $L3$

1. $\text{Tan } L3 = \frac{r}{l}$
2. $= \frac{l - q}{l}$
3. $j = \text{Sin}^2 A$
4. $b_2, c_2 = \text{Tan } A$
5. $z = \frac{j}{\text{Cos } B}$
6. $= \frac{\text{Sin}^2 A}{\text{Cos } B}$
7. $l = \frac{z}{\text{Cos } R}$
8. $= \frac{\text{Sin}^2 A}{\text{Cos } B \text{ Cos } R}$
9. $q = (b_2, c_2) \text{ Sin } R$
10. $= \text{Tan } A \text{ Sin } R$
11. $= \frac{\text{Sin } A \text{ Sin } R}{\text{Cos } A}$
12. $r = l - q$
13. $= \frac{\text{Sin}^2 A}{\text{Cos } B \text{ Cos } R} - \frac{\text{Sin } A \text{ Sin } R}{\text{Cos } A}$
14. $(e + z) = \frac{1}{\text{Cos } B}$
15. $l = (e + z) \text{ Sin } R$
16. $= \frac{1}{\text{Cos } B} \text{ Sin } R$
17. $= \frac{\text{Sin } R}{\text{Cos } B}$
18. $\therefore \text{Tan } L3 = \dfrac{\frac{\text{Sin}^2 A}{\text{Cos } B \text{ Cos } R} - \frac{\text{Sin } A \text{ Sin } R}{\text{Cos } A}}{\frac{\text{Sin } R}{\text{Cos } B}}$

ANALYTIC PROOFS

19. $$= \frac{\dfrac{\sin^2 A \cos A - \sin A \sin R \cos B \cos R}{\cos B \cos R \cos A}}{\dfrac{\sin R}{\cos B}}$$

20. $$= \frac{\sin^2 A \cos A - \sin A \cos^2 R \tan R \cos B}{\cos A \cos^2 R \tan R}$$

21. $$= \frac{\sin^2 A \cos A - \sin A \cos^2 R \tan A \cos^2 B}{\cos A \cos^2 R \tan A \cos B}$$

22. $$= \frac{\cos A \sin^2 A - \dfrac{\sin^2 A \cos^2 R \cos^2 B}{\cos A}}{\dfrac{\cos A \cos^2 R \sin A \cos B}{\cos A}}$$

23. $$= \frac{\dfrac{\cos^2 A \sin^2 A - \sin^2 A \cos^2 R \cos^2 B}{\cos A}}{\dfrac{\cos A \cos^2 R \sin A \cos B}{\cos A}}$$

24. $$= \frac{\cos^2 A \sin^2 A - \sin^2 A \cos^2 R \cos^2 B}{\cos A \cos^2 R \sin A \cos B}$$

25. But, r_2, b_2 $$= \sqrt{\frac{1}{\cos^2 B} + \tan^2 A}$$

26. $$= \sqrt{\frac{1}{\cos^2 B} + \frac{\sin^2 A}{\cos^2 A}}$$

27. $$= \sqrt{\frac{\cos^2 A + \sin^2 A \cos^2 B}{\cos^2 A \cos^2 B}}$$

28. $$= \frac{\sqrt{\sin^2 A \cos^2 B + \cos^2 A}}{\cos A \cos B}$$

29. $$\cos R = \frac{\dfrac{1}{\cos B}}{\dfrac{\sqrt{\sin^2 A \cos^2 B + \cos^2 A}}{\cos A \cos B}}$$

30. $$= \frac{\cos A}{\sqrt{\sin^2 A \cos^2 B + \cos^2 A}}$$

Hence by substitution in No. 24.

31. $$\tan \angle 3 = \frac{\sin^2 A \cos^2 A - \sin^2 A \left(\dfrac{\cos^2 A}{\sin^2 A \cos^2 B + \cos^2 A}\right) \cos^2 B}{\cos A \left(\dfrac{\cos^2 A}{\sin^2 A \cos^2 B + \cos^2 A}\right) \sin A \cos B}$$

32. $$= \frac{\dfrac{\sin^2 A \cos^2 A (\sin^2 A \cos^2 B + \cos^2 A) - \sin^2 A \cos^2 A \cos^2 B}{\sin^2 A \cos^2 B + \cos^2 A}}{\dfrac{\cos^3 A \sin A \cos B}{\sin^2 A \cos^2 B + \cos^2 A}}$$

33. $$= \frac{\sin A(\sin^2 A \cos^2 B + \cos^2 A) - \sin A \cos^2 B}{\cos A \cos B}$$

34. $$= \frac{\sin A(\sin^2 A \cos^2 B + \cos^2 A - \cos^2 B)}{\cos A \cos B}$$

35. $$= \frac{\sin A\,[\cos^2 B (\sin^2 A - 1) + \cos^2 A]}{\cos A \cos B}$$

36. $$= \frac{\sin A\,[\cos^2 B(-\cos^2 A) + \cos^2 A]}{\cos A \cos B}$$

37. $$= \frac{\sin A(\cos^2 A - \cos^2 A \cos^2 B)}{\cos A \cos B}$$

38. $$= \frac{\sin A \cos^2 A (1 - \cos^2 B)}{\cos A \cos B}$$

39. $$= \frac{\sin A \cos^2 A \sin^2 B}{\cos A \cos B}$$

40. $$= \sin A \cos A \sin B \tan B$$

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